STANDARDS FOR POSIX P.36

IEEE

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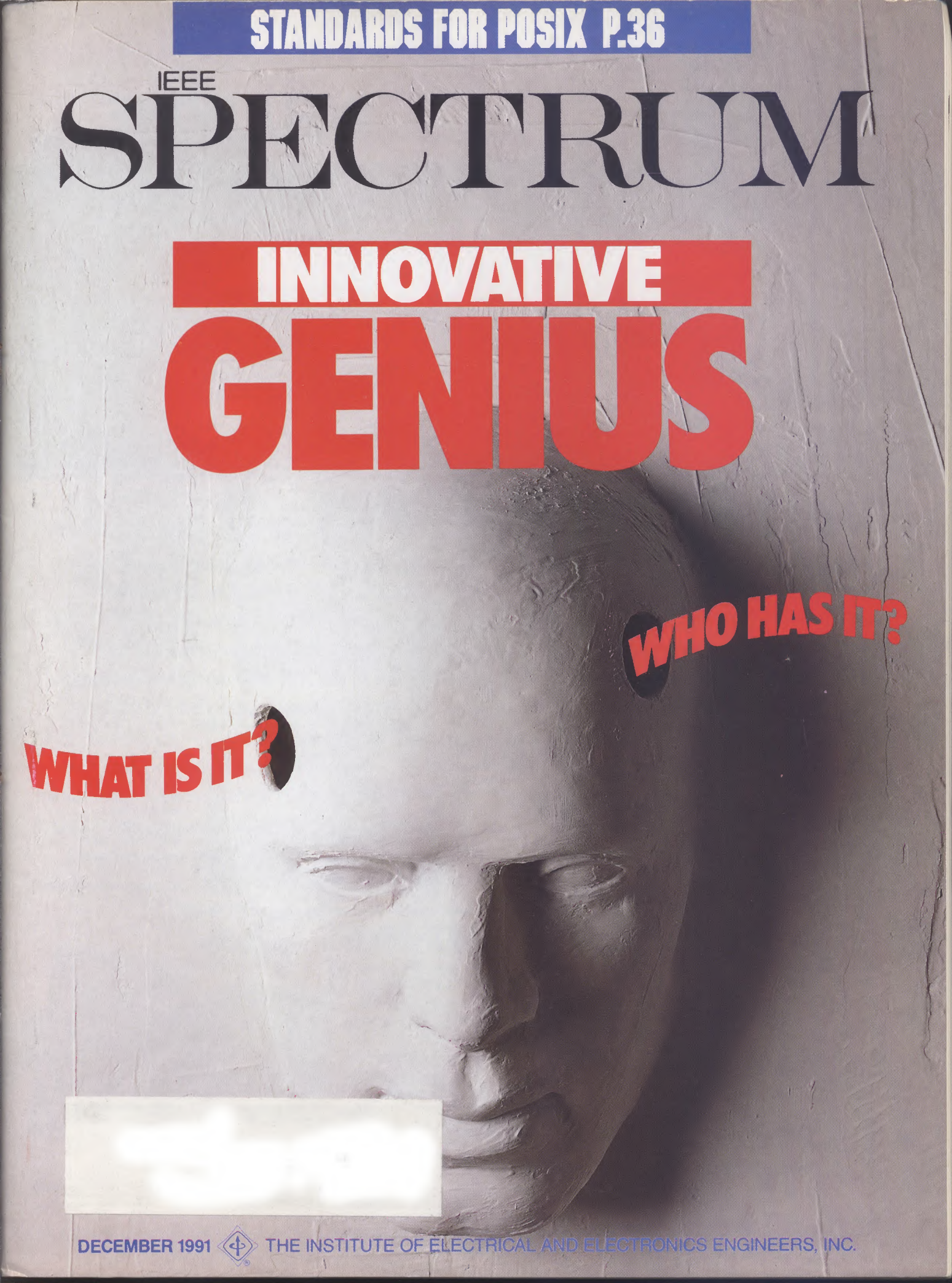
INNOVATIVE GENIUS



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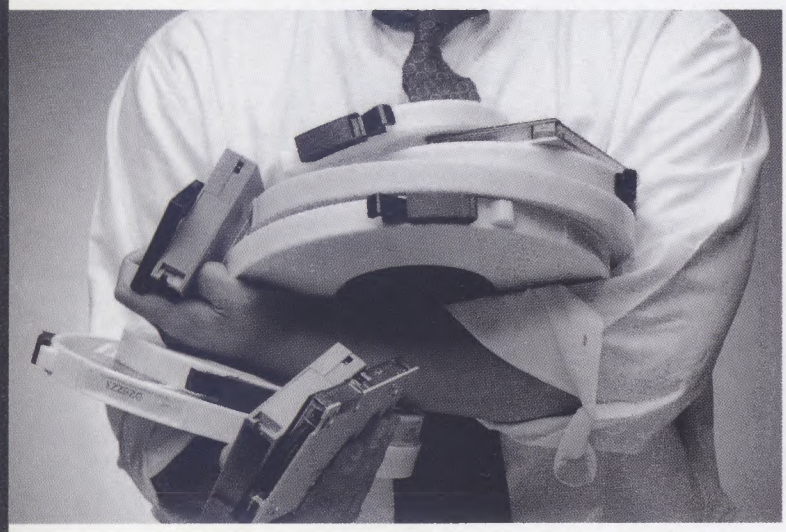

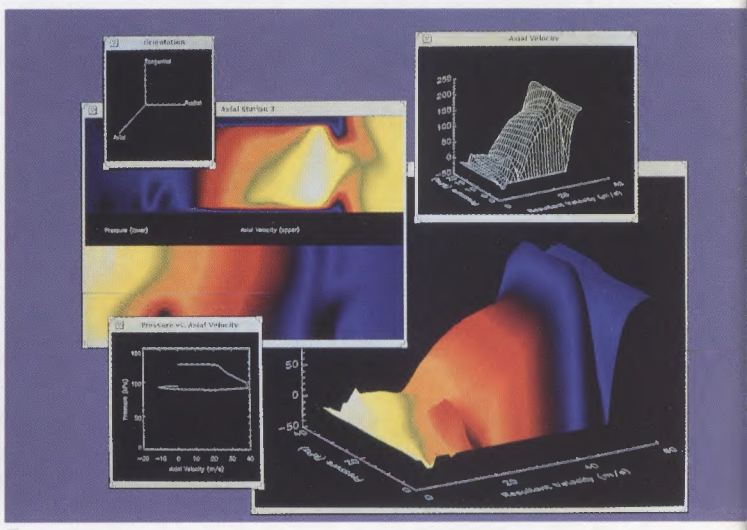

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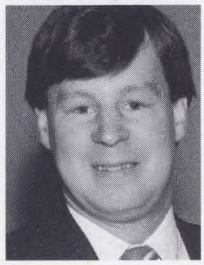

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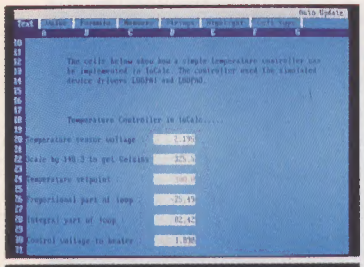

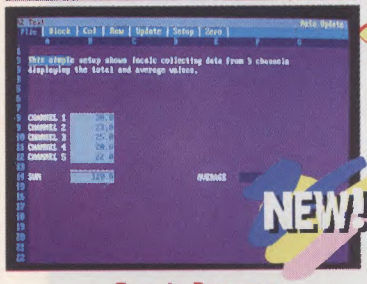

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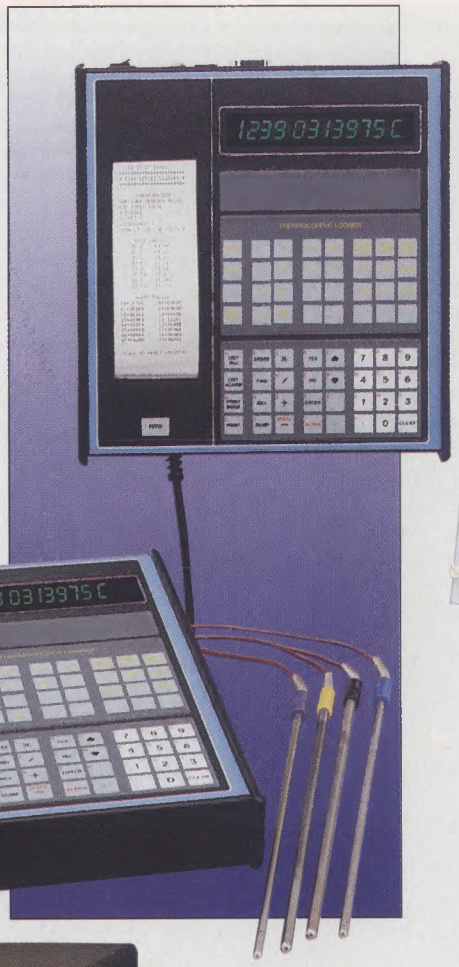

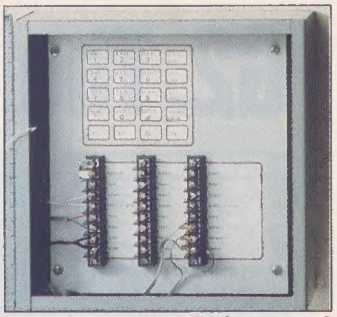

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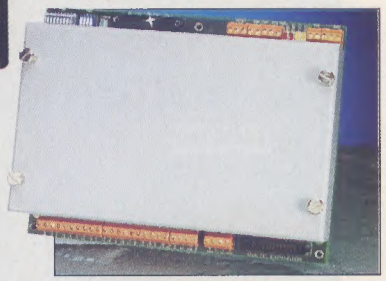

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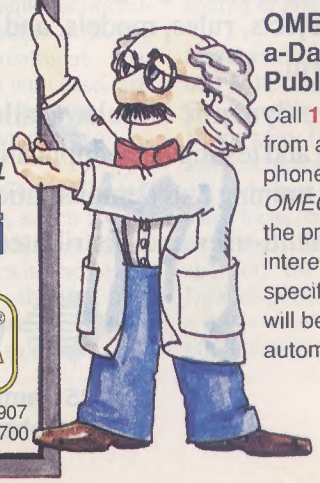

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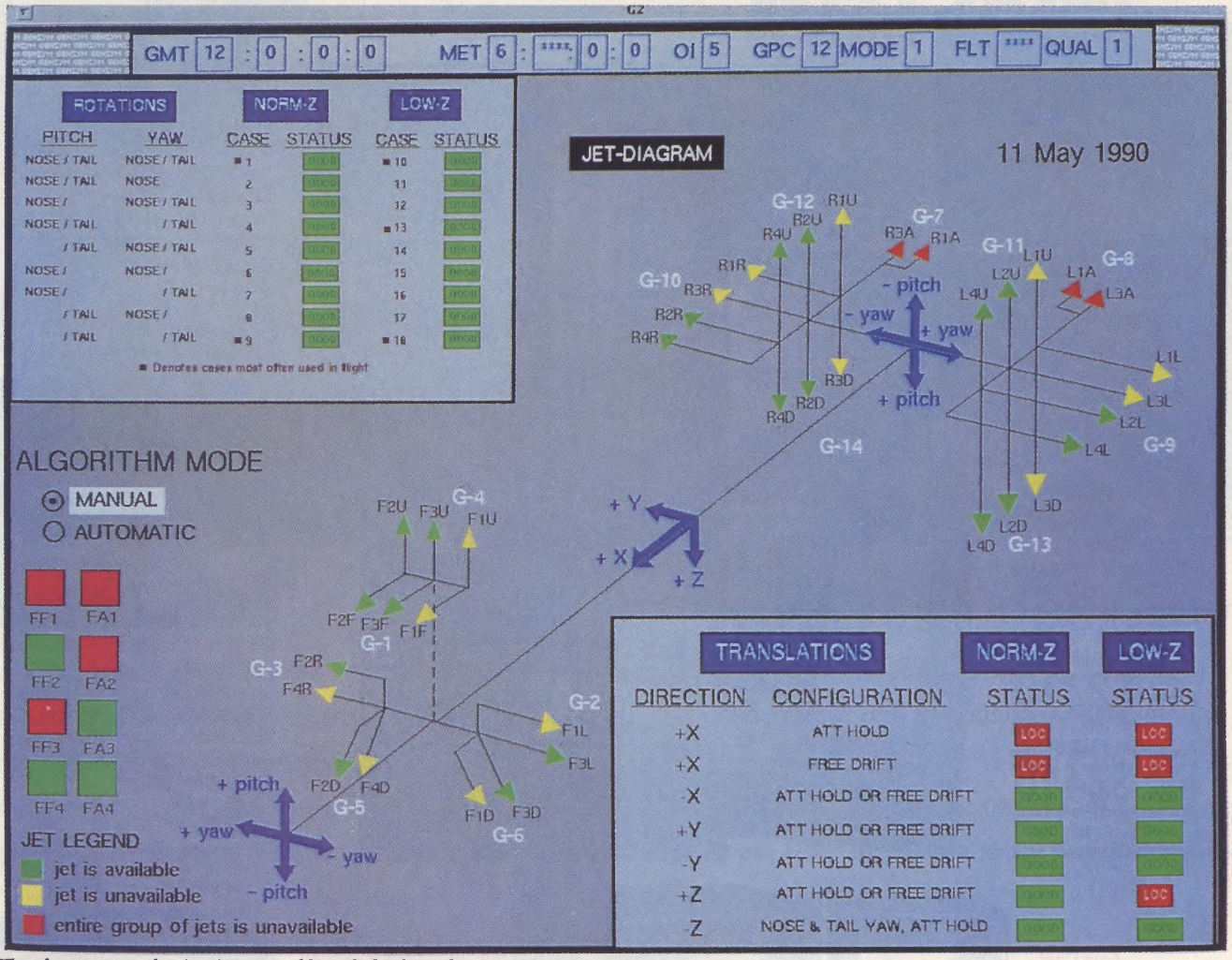

Courtesy of NASA Johnson Space Center.

The above screen shot is a jet-control knowledge base developed by NASA to monitor the space shuttle's 38 primary reaction jets through telemetry downlink.

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Newslog

OCT 9. The state-owned **Swedish Telecom** and **PTT Telecom Netherlands** have formed a joint venture, Unicom, to provide pan-European services to business customers. Unicom plans next year to have a network in 10 European countries with links to Japan and the United States.

OCT 16. **McCaw Cellular Communications Inc.**, Kirkland, Wash., said it will knit together its U.S. properties in the northeast, south, west, and northwest—covering a population of 60 million—in the **North American Cellular Network,** which it hopes will become the country's first national cellular telephone system. Analysts said the move infringes the monopoly on local service of the regional Bell operating companies and other operators.

OCT 22. The 12-nation **European Community (EC)** and the seven-member **European Free Trade Association** said they had agreed to form a new barrier-free common market of 380 million people in Western Europe. The world's largest trading bloc, to be called the **European Economic Area,** will go into effect on Jan. 1, 1993.

OCT 24. **Michael Grätzel,** a Swiss scientist, and his U.S. colleague **Brian O'Regan,** working at the Swiss Federal Institute of Technology in Lausanne, said they had developed a new kind of photovoltaic cell that converts diffused sunlight into electric current at an efficiency of 12 percent. The **Grätzel-O'Regan cell** thus rivals the performance of the best amorphous silicon cells, but would cost much less to manufacture.

OCT 24. The **Federal Communications Commission,** Washington, D.C., proposed that local telephone companies be allowed to package and transmit television programming by installing a new video technology called video dial tone. Consumers would view cable programs on TV sets linked to their phone lines, and would be charged accordingly. The proposal could become effective within a year.

OCT 25. AEG AG, part of the Daimler-Benz AG group of Germany, said it has agreed to sell **AEG Kabel AG,** its cable unit, to **Alcatel Alsthom SA** of France. The cable company employs 5000 people and had sales last year of DM 1.7 billion (US $1 billion). The purchase will lift Alcatel Cable's share in the German market from 10 to nearly 25 percent.

OCT 29. The **Galileo** spacecraft flew within 1600 km of the **asteroid Gaspra** for the first encounter between a spacecraft and an asteroid. Officials at the National Aeronautics and Space Administration said the spacecraft photographed the asteroid—which has a diameter of no more than 13 km—and gathered remotely sensed data on Gaspra's chemical composition.

OCT 29. **Toshiba Corp.** and **C. Itoh & Co.** of Japan said they would buy a US $1 billion, 12.5 percent stake in a new joint venture that will include the film and cable television operations of **Time Warner Corp.** The new U.S. subsidiary, to be called Time Warner Entertainment, will include movie studio Warner Brothers, pay-TV programmer Home Box Office, and cable operator Time Warner Cable.

OCT 31. The U.S. **Supreme Court** said the **seven regional Bell telephone companies** can immediately begin offering electronic information services. The court denied an appeal by a coalition of newspaper, broadcasting, cable television, and other companies that had sought to delay an October ruling to that effect by a Federal appeals court.

NOV 5. **Toshiba Corp.,** Tokyo, said it had developed the tiniest yet electric motor, which is minuscule enough to travel inside the human body. The company said the motor packs bearings, magnet, coils, and the rest within an outside diameter of 2.5 mm. Driving power for the motor is only 2–3 V.

NOV 6. Researchers at Japan's **NEC Corp.** said they had discovered a crystalline form of carbon in a tubular form of buckyballs (spherical carbon molecules). The buckytubes—long cylindrical meshes of carbon atoms capped by domes resembling buckyballs cut in half—may be the strongest fibers ever made. Consisting of up to 10 concentric layers of carbon atoms, which taper off in needle-like shapes, the tubes are formed at 2000 °C and are 2.2–30 nm in diameter.

NOV 6. **North American Philips Corp.,** New York City, a U.S. unit of **Philips NV,** the Netherlands, said it had licensed 23 U.S. patents of California inventor **Gilbert P. Hyatt,** including the one for a single-chip computer, which was granted last year after a 20-year wait. Philips said it would help license Hyatt's patents worldwide.

NOV 6. Scientists at **Northwestern University,** Evanston, Ill., said they had discovered a way to more easily crystallize thin films of diamond. Using buckyballs as molecular seeds for growing diamond films, the technique allows engineers to dispense with the diamond-grit treatment, coat curved surfaces with ease, and more cheaply cover large surfaces with diamond.

NOV 7. **International Chetek Corp.,** Moscow, said it is selling underground nuclear explosions for commercial and peaceful applications—the first time nuclear blasts are known to have been put up for sale. The company's initial goal is to incinerate toxic wastes in the USSR, but the blasts are also being sold worldwide.

NOV 7. **IBM Corp.** announced a 10-year agreement with **Intel Corp.,** Santa Clara, Calif., to design central processing units for coming generations of personal computers. The new chips will be made by IBM at its own plants for use in its PCs, and by Intel for sale to other computer makers. The jointly developed devices will be based on Intel's latest microprocessors, including its 486 version.

NOV 7. Scientists at **AT&T's Bell Laboratories** announced that they had produced the world's smallest lasers by alternating one or more layers of indium gallium arsenide with layers of indium gallium arsenide phosphide. With the thin layers that constitute the laser head being only 400 atoms thick, the researchers etched away some material to leave tiny thumbtack-shaped structures that can emit laser light in several directions.

NOV 9. Researchers at the **Joint European Torus,** a fusion reactor in Oxfordshire, England, said they had produced a significant amount of power from controlled nuclear fusion after adding tritium to the fuel mix in their fusion reactor. The achievement puts a European team from 14 countries ahead of Soviet, Japanese, and U.S. rivals in developing fusion as a new source of energy.

Preview:
DEC 8–11. The **International Electron Devices Meeting** in Washington, D.C., is to highlight manufacturability and profitability concerns in addition to its usual focus on research. For information, call the meeting's sponsor, the IEEE Electron Devices Society: 202-347-5900.

COORDINATOR: Sally Cahur

DECEMBER 1991 Volume 28 Number 12

IEEE
SPECTRUM

SPECIAL REPORT/CAREERS

INNOVATIVE GENIUS

The nature of technical creativity is illuminated by eight outstanding contemporary innovators in electronics, and analyzed by an eminent psychologist.

23 The innovative mind at work

By MICHAEL MACCOBY

The innovators in this special report have much in common. They regard work as play. They choose big problems with large implications—for example, communicating by satellite or revolutionizing power transmission. They are used to resistance to their ideas but are independent and courageous enough to forge ahead on their own.

Profiles prepared by *Spectrum* editors describe the makeup of eight innovators in our industry, beginning on p. 24. Jacob Rabinow, Carver A. Mead, Masaru Ibuka, John R. Pierce, James F. Blinn, Jun-ichi Nishizawa, Charles H. Townes, and John Cocke have each made many important contributions over long careers, often in diverse technologies. The men speak of their backgrounds, achievements, work habits, interests, and feelings about creativity and innovation.

Each has been undaunted by failure; indeed, they learn from adversity and build on it to reach their goals. Their motivations are largely altruistic and strikingly similar: they speak variously of improving human living conditions and conveying to others the fun they find in science and mathematics.

Their stories shed light on the nature of innovation and provide insights into how to nurture and guide it. They offer encouragement to seasoned engineers beset by the specter of technological obsolescence and inspiration to engineers just starting their careers.

APPLICATIONS/SOFTWARE

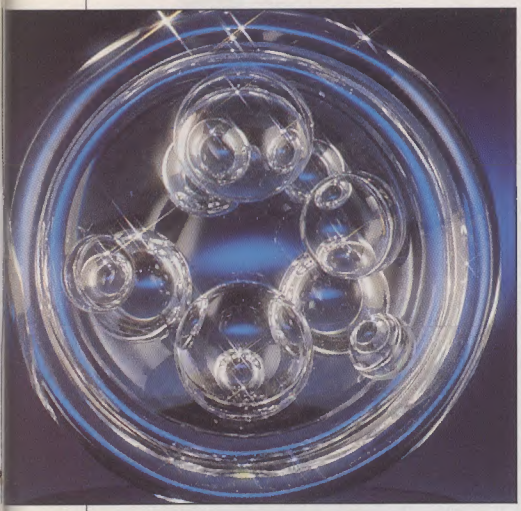
36 IEEE's Posix: making progress

By D. RICHARD KUHN

Mark Helfer, NIST

Researchers with the National Institute of Standards and Technology, Gaithersburg, Md., here review an application of open system software. Standards for such open systems are being developed within the IEEE portable operating system interface—Posix, for short.

THE INSTITUTE



SPECTRAL LINES

Cover: Probing the innovative mind is the subject of this stark sculpture by designer Gus Sauter. See p. 22.
Photo: Chuck Kintzing.

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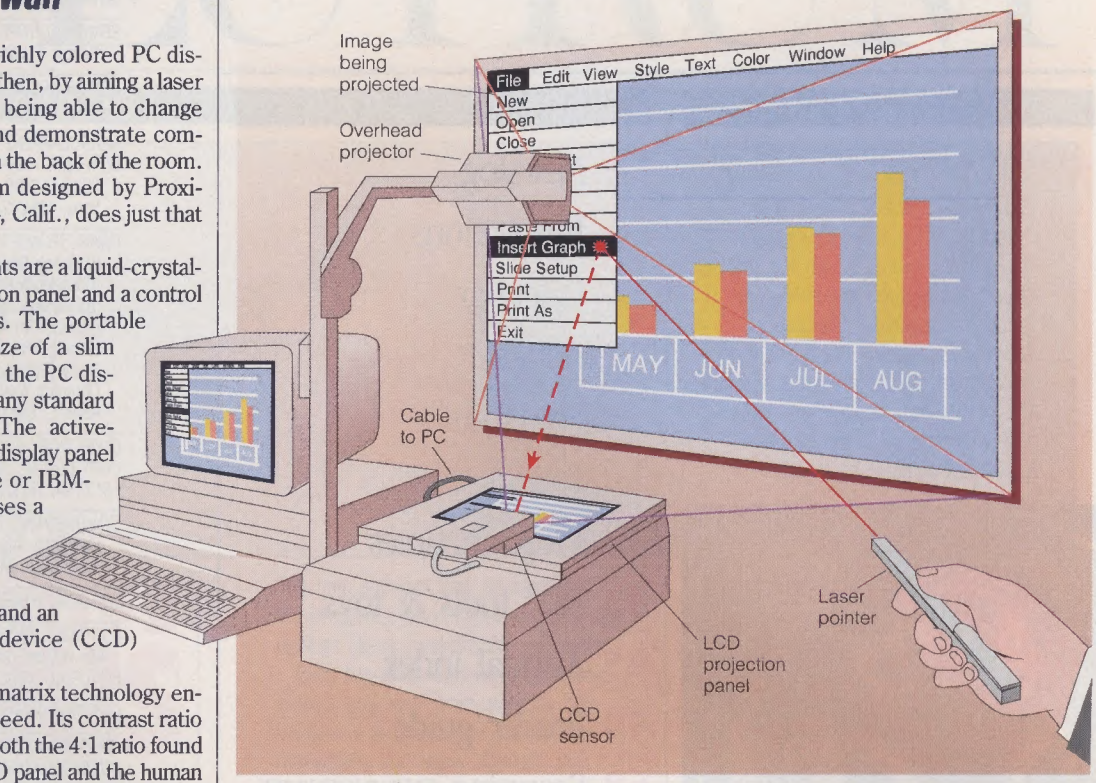
Innovations

Writing on the wall

Imagine projecting a richly colored PC display onto a screen and then, by aiming a laser pointer at the screen, being able to change menus, drag icons, and demonstrate computer graphics, all from the back of the room. The projection system designed by Proxima Corp. of San Diego, Calif., does just that for its user.

Its two basic elements are a liquid-crystal-display (LCD) projection panel and a control system called Cyclops. The portable panel, which is the size of a slim briefcase, reproduces the PC display for projection by any standard overhead projector. The active-matrix full-color LCD display panel works with any Apple or IBM-compatible PC that uses a mouse. Cyclops includes a light-emitting-diode (LED) wand or laser pointer and an area charge-coupled-device (CCD) image sensor.



The panel's active-matrix technology enhances contrast and speed. Its contrast ratio of 100:1 is well above both the 4:1 ratio found in a passive-matrix LCD panel and the human eye's 60:1 contrast ratio perception. The picture elements, or pixels, can be turned on and off in about 50 ms, allowing panels to be used for video projection. A separate board for logic conversion is included in the panel. Because the active-matrix panel has a field-effect transistor and storage capacitor at each pixel, cross talk, or streaking, is eliminated. Also, since each pixel has its own driver, there is no interference.

According to Lane Hauck, senior staff engineer, the degradation of contrast by high temperatures is avoided by a built-in fan that draws air over the panel. An infrared shield deflects heat from the overhead projector bulb.

Cyclops' CCD sensor is attached to the rear edge of the panel [see figure]. Both the wand and pointer project a bright spot of light onto the screen. The sensor eye views the screen, detects the LED or laser spot, translates its location into x and y coordinates, then transmits this information through the serial port to the PC (or through the Apple Bus to the Macintosh). A device driver reads the port and converts the coordinates into display screen coordinates. It updates the coordinates as a mouse would, and, in essence, replaces the mouse driver.

All panels come with an infrared remote control that can be used to move sequentially through menus and screens and to control panel functions. An infrared receiver with single-chip processing is located on the front of the panel.

The Proxima projection system, including color panel and Cyclops, ranges from US $5990 to $10 086. Cabling, infrared remote control, and utility software are included with the panel, the most expensive version of which has video and audio hookup capabilities. Monochrome panels costing from $999 to $2199 are also available. A switch on all panels makes rear projection possible. The optional laser pointer costs $396. *Contact: Proxima Corporation Inc., 6610 Nancy Ridge Dr., San Diego, Calif. 92121-3294; 619-457-5500; fax, 619-457-9647.*

Single-atom control

With the flip of a switch, a single xenon atom changes position and alters the resistance and tunneling current measured between two electrodes. The discovery of this single-atom switch, made by scientists Donald M. Eigler, Christopher P. Lutz, and William E. Rudge at IBM Research Division's Almaden Research Center in San Jose, Calif., may lay the foundation for constructing electronic circuits with atomic-scale dimensions. Atomic-scale logic and memory would be a million or more times smaller than today's micrometer-scale circuits. Information of greater complexity would be stored and retrieved more quickly and less expensively.

Of the switch's two electrodes, one was the scanning tunneling microscope (STM) tip. Composed of polycrystalline tungsten wire, the STM uses a fine stylus to trace out and image surface details with atomic resolution. The other was a single-crystal nickel surface located only a few atomic diameters away. When a voltage pulse was applied across the leads, the xenon atom moved from the microscope tip to the nickel surface, changing the conductance across the leads. By reversing the polarity of the voltage pulse, the xenon atom returned to the microscope tip, and the conductance went back to its previous level.

Since it operates in an ultrahigh vacuum at temperatures around 4 K, the single-atom switch is not yet practicable. Moreover, compact devices would require that the switches be packed tightly together and connected by highly miniaturized leads.

Eigler said he and his fellow scientists want next to better understand the switch's mechanism. They also expect that other molecules having all the features of self-contained atomic-scale switches will eventually be discovered.

COORDINATOR: Dana Norvila
CONSULTANT: Ralph H. Baer

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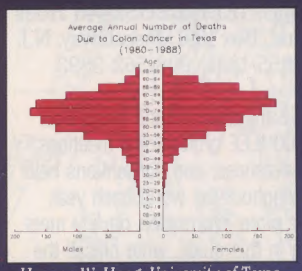
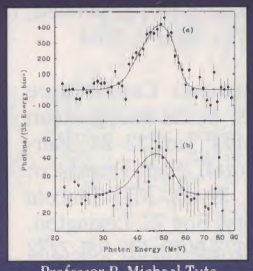
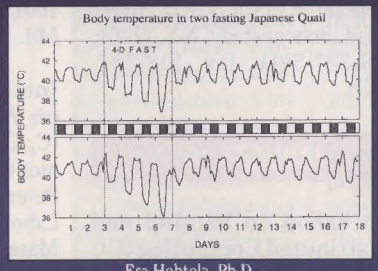


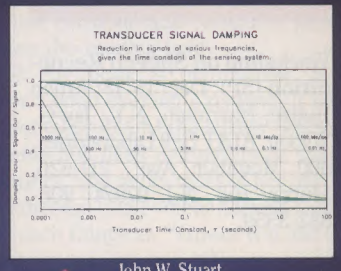
Herman W. Hong, University of Texas, M.D. Anderson Cancer Center[1]



Professor P. Michael Tuts
Columbia University



Esa Hohtola, Ph.D.
University of Oulu, Finland[2]



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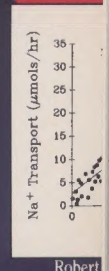
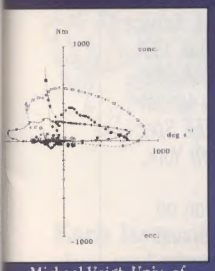
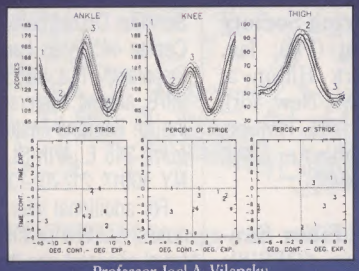


Robert
University



Michael Voigt, Univ. of Copenhagen, Denmark



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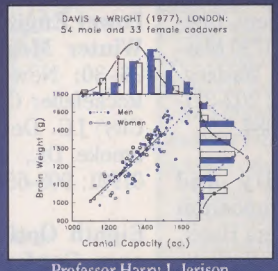
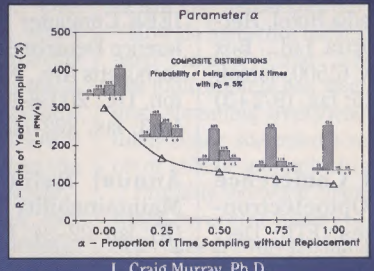
Indiana University



Professor Harry J. Jerison
UCLA Medical School



L. Craig Murray, Ph.D.
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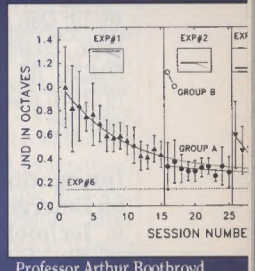
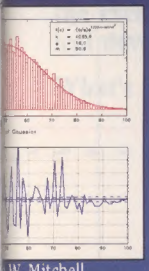


Professor Arthur Boothroyd
City University of New York[3]



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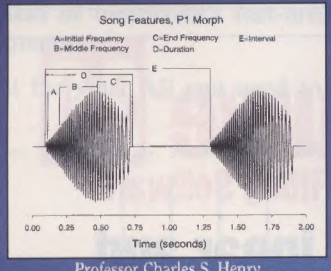

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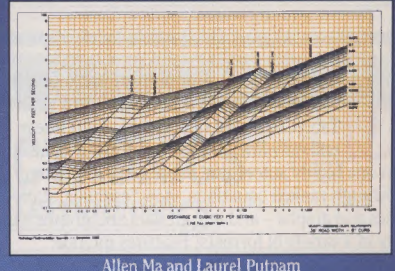

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Meetings, Conferences and Conventions

DECEMBER

Workshop on Speech Recognition (SP); Dec. 15–18; Arden House, Harriman, N.Y.; Jay G. Wilpon, AT&T Bell Laboratories, 600 Mountain Ave., 2D-526, Murray Hill, N.J. 07974; 908-582-3559.

International Commsphere 91 Symposium (C, AP); Dec. 16–19; Dan Accadia Hotel, Herzliya, Israel; Ortra Ltd., Box 50432, Tel Aviv 61500, Israel; (972+3) 664 825; fax, (972+3) 660 952.

International Conference on Emerging Optoelectronic Technologies (ED); Dec. 16–20; Indian Institute of Science, Bangalore, India; Krishna Shenai, KW-A1715, General Electric CRD, River Road, Schenectady, N.Y. 12301; 518-387-5911; fax, 518-387-5058.

JANUARY 1992

Workshop on Parallel and Distributed Computing (C); Jan. 20–22; Hyatt Regency Hotel, Newport Beach, Calif.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Annual Reliability and Maintainability Symposium (R); Jan. 22–24; Riviera Hotel, Las Vegas, Nev.; R.E. Sackett, Hernandez Engineering Inc., Commerce Center II, Suite 305; 7601 Ora Glen Dr., Greenbelt, Md. 20770; 301-441-3204.

International Conference on Wafer Scale Integration (C, CHMT); Jan. 22–24; Fairmont Hotel, San Francisco; Peter W. Wyatt, MIT Lincoln Laboratory, Box 73, Lexington, Mass. 02173-0073; 617-981-7232 or 617-862-9057.

Power Engineering Society Winter Meeting (PE); Jan. 26–30; New York Hilton at Rockefeller Center, New York City; J.G. Derse, 704 Timberbrooke Dr., Bedminster, N.J. 07921; 908-658-4042.

Eighth Optical Fiber Sensors Conference (OFS'8); (LEO); Jan. 29–31; Monterey Marriott Hotel, Monterey, Calif.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3893.

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her tales describe how for stealing money, al-s, and being involved in, es. There are also anec-ious (like Charles Bab-nann, and Alan M. Tur-nt the revolutions of his ow when to fix a loose ous ("Captain Crunch" come to mind).
: *A Space Odyssey* and l by the author for their vil. In other stories com-n myriad ways because dling, and "bugs." One famous bug that vexed Grace Hopper (Jennings he word bug to mean " to Thomas Edison). t another familiar word, by none other than the r, the late Dr. Seuss. e well arranged into ns—hackers, viruses, n, and cybernetic gods, l index enables readers to look up computer tales about Marvin Minsky or Brian W. Kernighan's account of the naming of Unix, for example. Also, the inclusion of cartoons and computer jokes helps keep the reading light.

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Books

The fungus that ate data

Larry Kaplan

The Devouring Fungus: Tales of the Computer Age.
Jennings, Karla, W.W. Norton, New York, 1990, 237 pp., US $19.95.

How did a New York bank teller use a computer to embezzle US $1.5 million? What type of sabotage did a former *Encyclopaedia Britannica* employee commit? Where did the word FUBAR come from?

The answers to those questions, and hundreds of other computer tales, can be found in this book, a collection of folklore, stories, anecdotes, and jokes. It includes most of the well-known stories on such subjects as *Star Trek*, hackers, viruses, and "compuspeak." Other tales describe how computers are used for stealing money, altering credit histories, and being involved in, and for, practical jokes. There are also anecdotes about the famous (like Charles Babbage, John Von Neumann, and Alan M. Turing, who used to count the revolutions of his bicycle wheel to know when to fix a loose chain) and the infamous ("Captain Crunch" and John C. Dvorak come to mind).

The movies *2001: A Space Odyssey* and *Aliens* are compared by the author for their views of computer evil. In other stories computers break down in myriad ways because of misuse, faulty handling, and "bugs." One tale describes the famous bug that vexed computer pioneer Grace Hopper (Jennings traces the use of the word bug to mean "technical problem" to Thomas Edison). She also reveals that another familiar word, nerd, was invented by none other than the children's storyteller, the late Dr. Seuss.

The chapters are well arranged into meaningful divisions—hackers, viruses, money, the bedroom, and cybernetic gods, among them. A good index enables readers to look up computer tales about Marvin Minsky or Brian W. Kernighan's account of the naming of Unix, for example. Also, the inclusion of cartoons and computer jokes helps keep the reading light.

Though the book is entertaining and makes for a good evening's reading, it has a fundamental problem: the author neither understands nor likes computers or their programmers. She vents most of her nastiness on crackers (malevolent hackers), but she says such things as "Guess you had to be there to appreciate it," "Nerds can still sometimes be seen lurking in the alleyways of San Jose, especially during a full moon," "How do hard-core hackers reproduce, anyway? Viruses?," and "The computer's social infiltration is like that [devouring] fungus, spreading everywhere." These and many other statements reveal a basic fear of, or at least antipathy toward, computing.

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Books

ries, even though one of its sources is the Jargon File, a listing of various hacker terms and stories originating and maintained on an electronic network (the file was once edited by Guy Steele into a book called *The Hacker's Dictionary*, recently revived by Eric S. Raymond and MIT Press in Cambridge, Mass. [see *IEEE Spectrum*, November 1991, p. 18]). Constantly revised by readers who send in their additions or corrections through electronic mail and network posting, the file—page for page—contains more information and humor than most of *The Devouring Fungus* and is much more current.

Much is missing from the book. For one, there is no bibliography (although the introduction promises a "source guide"). Jennings quotes Steven Levy, Clifford Stoll, and Jan Harold Brunvald but does not bother to name their books—*Hackers*, *The Cuckoo's Egg*, and *Vanishing Hitchhiker*. She obviously used some printed material from other sources, but does not cite them either. Also, although an entire chapter is spent on viruses, the author seems oblivious to the many parallels between human and computer viruses. (Programs to detect viruses are called disinfectants or doctors; preventative programs are called condoms—sharing internal data is the only way to spread "disease.")

Factually, each tale is either true or false, and Jennings manages to trace some histories and verify a few stories. But most are left untouched—just retold with no concern for veracity, which is apparently left as a reader exercise. The author dismisses the many sexist, stereotypical stories of secretaries who accidently damage their computers or files as implausible and absurd. Yet she accepts as absolute truth the story of a program that had such a low priority that it was never run in its six-year life-span.

After reading the book, I thought of what it could have been. I wished it were written by Brunvald, who would have researched every myth and traced its history and validity. Had Levy written it, his knack for capturing people and personalities would have made the stories come alive.

It would also have been fascinating to know what Donald Knuth or Nicholas Wirth think about the myths surrounding them and their craft. It would be a delight to know whether the devouring fungus story—about an actual biological fungus that obliterated data on magnetic tape and for which the book is titled—really happened.

Nowhere in the book is the wonder that computer people feel, the beauty that they have unleashed, or the glimpses into the future that they have helped create. With only a little more effort, both the bad and good sides of computers and their disciples could have been revealed.

Once upon a time, Larry Kaplan designed video games for a living. Nowadays, he has fun programming computers for audio and video applications at Silicon Graphics Inc. in Mountain View, Calif. He lives in Silicon Valley with his wife, Sue, his three sons, Benjy, David, and Jonathan, and his Mac, Amiga, and MIDI keyboards.

COORDINATOR: Glenn Zorpette

Recent books

Cable Nets and Tensegric Shells: analysis and design applications. *Vilnay, Oren*, Prentice-Hall, Englewood Cliffs, N.J., 1991, 130 pp., $65.95.

Trends in Theoretical Physics, Vol. 2. Eds. *Ellis, Paul J.*, and *Tang, Y.C.*, Addison-Wesley, Redwood City, Calif., 1991, 416 pp., $48.50.

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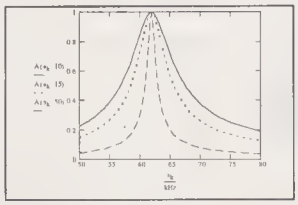

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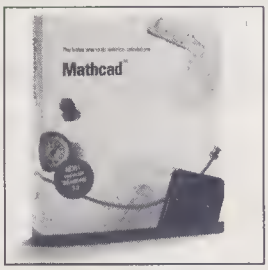

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Circle No. 13

Speakout

R&D engineers lack a voice

I am uneasy as I follow the battle that has raged for the last few years in the United States between Big Science and Little Science. Constituencies of scientists and engineers, politicians, and government officials argue articulately on behalf of their own needs. Each cites lofty goals: preservation of national freedoms, global competitiveness, international prestige, and boosts in our quality of life, which, they assert, depend directly on the continued investment of public funds in their brands of science.

The good news is that both camps are probably right. The bad news is that in all this discussion, no one speaks for the R&D engineer—the person who can develop an idea uncovered in a laboratory to the point of proving its feasibility. A lot of good ideas that could contribute to U.S. competitiveness are today stuck in the laboratory, ignored for lack of funds.

Arguing for Little Science, National Academy of Sciences president Frank Press has called for setting tougher priorities for Big Science projects while increasing support for Little Science to safeguard the country's scientific infrastructure. More recently, Leon Lederman, former director of Big Science's Fermilab, brandished the results of a poll that indicated university scientists—the Little Science people—never felt more financially strapped.

One Big Science star, Space Station Freedom, almost lost its right-to-life this year when congressional debate heated up, fueled by more than a dozen technical societies, including the IEEE, which claimed little technical justification for the US $32 billion station. The Superconducting Supercollider faces a similar challenge as its passed hat keeps coming back—all but empty from our international colleagues in the high-energy physics Big Leagues. Nevertheless, Freedom and the collider are proceeding.

In this budgetary shoot-out, no one ever considers the R&D engineer, whether in Government, on campus, or in a corporation. No champion exists for his/her essential contribution: exploratory development. These folks take our country's most promising basic research and determine whether it can be integrated, packaged, and manufactured economically. We are standing by and allowing aggressive foreign laboratories to pick up our ideas before U.S. markets can exploit them.

Speakout

In a previous life as a theoretical physicist, I scoffed at the less lofty pursuits of my engineering colleagues as I handed them my calculations to hammer into applications. Today, as a manager of Federal R&D programs in both basic research and early engineering development, I see the picture much differently. My files are bursting with scientific accomplishments crying for more funds to thrust them into the development stage. Some examples:

In 1986 my office and the Office of Naval Research began a mini-materials revolution with a research thrust in artificial thin-film diamond. With only $3 million a year from the Strategic Defense Initiative Organization (SDIO) and some industry investment, the field has grown from a few groups researching this exceptional material with its many applications to a community that supports three-day conferences at least twice a year and a quarterly technical journal. Last spring, *Science* magazine proclaimed diamond the Molecule of the Year.

Industry is leading the charge in the fabrication of polycrystalline diamond films with early products like coatings, radomes, acoustic speakers, semiconductor substrates, and mask supports for X-ray lithography. But the big payoff remains just out of reach—we must still grow single-crystal diamond. Once this is accomplished, we will be able to produce refractory semiconductors and high-power optical elements to revolutionize automotive electronics, high-power switches and lasers, and modern ultraviolet sensors.

But Government funding has grown to only $6 million, far too meager to support major device engineering efforts. Yet in Japan, the Ministry of Trade and Industry recently launched a $40-million-a-year effort to learn to make diamond semiconductors.

Another area is superconducting electronics using low-temperature niobium or niobium nitride. SDIO sponsors efforts, managed by the Air Force's Rome Laboratory and the Office of Naval Research, to develop devices for signal processing and infrared detection. Researchers have for seven years continually improved analog-to-digital converters, phase shifters, transimpedance amplifiers, Squids (superconducting quantum interference devices), and focal plane arrays, which demonstrate higher speed and lower power dissipation than their semiconductor counterparts.

The field has been ready for device integration for at least three years. Lacking are the funds to produce terahertz communication systems, high-resolution imagers, and superfast signal and data processors. Government backers have tried for years without success to energize multi-agency support for a foundry to produce superconducting electronics. And so, while U.S. researchers work on single-Josephson-junction niobium devices, engineers at Fujitsu Ltd. and Hitachi Ltd. routinely turn out 8-bit microprocessors as they push for large-scale integration devices.

An area where the United States still holds a commanding lead is satellite communications. But as the hunger for more bandwidth and higher data rates increases, we should be pushing into the next frontier—free-space optical communications. U.S. researchers are pursuing improvements in a number of transmitter and receiver technologies, including higher-power laser diodes, wide field-of-view acquisition, accurate tracking and pointing, and high-speed data processing. SDIO, the National Aeronautics and Space Administration, the Air Force, and industry each have a first-generation system as their long-range goal.

The embarrassing situation is that the devices are ready for demonstration today! More than a year ago, a videotape of the movie *Star Wars* was sent optically across 10 meters of an SDIO conference room. Even against a brightly reflective "earth" background, the receiver acquired and locked on to the narrow-beam laser signal. But funds to push the technology into an integrated prototype or a modest demonstration on a space platform are nowhere to be found. No one seems interested in pushing the frontier until the bandwidth crunch reaches crisis levels. Both Europe and Japan have made major investments in the aggressive pursuit of this new technology.

Finally, we have photonics. This promising field, which produces semiconductor lasers and optoelectronic devices for advanced networking, optical processing, consumer electronics, and a thousand other applications, is struggling for respect in a silicon world. University researchers have crafted a gold mine of nonlinear optical materials and blinding-speed laboratory devices. But where are the development funds to package a square meter of optical bench on a single chip?

I'm sure you have your own candidates to add to my four examples, but the point is made. I don't question the achievements of our country's scientists and their basic research; they can be justly proud of their fine contributions. Nor do I doubt that many large initiatives like human genome mapping will improve our lot.

But if our technology gurus are successful with their cry for another increment of government dollars, priority should be given to our R&D engineers. From what I see, they're eager to transform the world's best science into the world's best technology.

—Dwight Duston

Dwight Duston (SM) is director of the Strategic Defense Initiative's Innovative Science and Technology Office in Washington, D.C. He earned his Ph.D. in physics from the University of Michigan, Ann Arbor.

Forum

Support in a storm

I was elated to see someone finally give credit to the technical reps who supported Operation Desert Storm ["From factory floor to desert war," by Glenn Zorpette, September, p. 41].

I have been employed by Picker International Inc. for the last 23 years and never thought I would personally be involved in a shooting war; I am 54 years old. But before the war, Picker International and [parent company] GEC Medical Equipment Ltd. [of Wembley, UK] had separately volunteered to participate with the U.S. Army Surgeon General's Office in the testing and developing of a field-deployable medical X-ray CT [computed tomography] scanner system. The Army decided to deploy the commercially available CT scanners in Saudi Arabia in support of our medical corps.

The CT scanners were not designed to military specification for field deployment. Picker and GEC each modified their scanners to fit in the Army's standard ISO shelter, with a shock absorber system for survival during transportation.

There was not sufficient time, however, once the decision was made, to fully train Government service personnel. So the Army asked for volunteers from Picker and GEC. I decided to help because of my knowledge of the Army's fielding requirements, obtained during the clinical trials, and the scanners' requirements.

I was made a little apprehensive, when we landed at Dhahran air base on Jan. 16 at 12:30 a.m., by the sounds of our fighter bombers taking off for their first runs. We traveled in C5A MAC aircraft with our equipment, to prevent it from getting lost.

Service and operator training for the Government personnel was started in the United States and continued in Saudi Arabia. The Picker International IQ CT scanner was sent to the Army's 12th Evac Hospital, located about 40 km below the Iraq-Kuwait border.

I only spent two weeks in the area, but I felt that my efforts were worth the hardships. I was told by the CT scanner operators that the life of the first patient, an accident victim, examined on the scanner was saved because this high-tech equipment was available to the doctors. They diagnosed his internal injuries at the field hospital level, and immediately operated before the patient was transported to a rear hospital. Without the knowledge of his internal injuries, the patient probably would not have survived the transporting.

I found the articles to be very accurate in the areas of my involvement, but can add that tech reps received the required overseas inoculation shots ("ouch"). I also ate food from a plastic bag and slept in a tent right next to my gas mask and chemical warfare suit with the soldiers. I did not receive a sizeable bonus, but that was not one of my reasons for going.

Recently the Army purchased Picker's CT scanner system. It was on lease during its deployment in Saudi Arabia.

Frank J. Oblak
Highland Heights, Ohio

Powerful forces

J. Robert Ashley errs in his rejoinder to James Wait's letter [August, p. 14] with respect to several points:

Power-line radiation observations made at Roberval, Quebec, and at Siple Station, Antarctica, were reported at least 16 years ago (see both R. A. Helliwell, *et al.*, "VLF line radiation in the earth's magnetosphere and its association with power system radiation," *J. Geophys. Res.*, Vol. 80, no. 31, pp. 4249–4258, November 1975; and H. R. Leuchtag, "Power-line radiation affects Earth's magnetosphere," *Phys. Today*, Vol. 28, no. 12, pp. 17–19, December 1975; also noted in *Industrial Research*, p. 38, January 1976).

If Maxwell's equations give a valid description of electromagnetic fields on a macroscopic scale, the field vectors are uniquely specified because both their curls and divergences are specified.

Furthermore, Maxwell's equations show that in the case of time variations, the electric and magnetic fields are inextricably coupled.

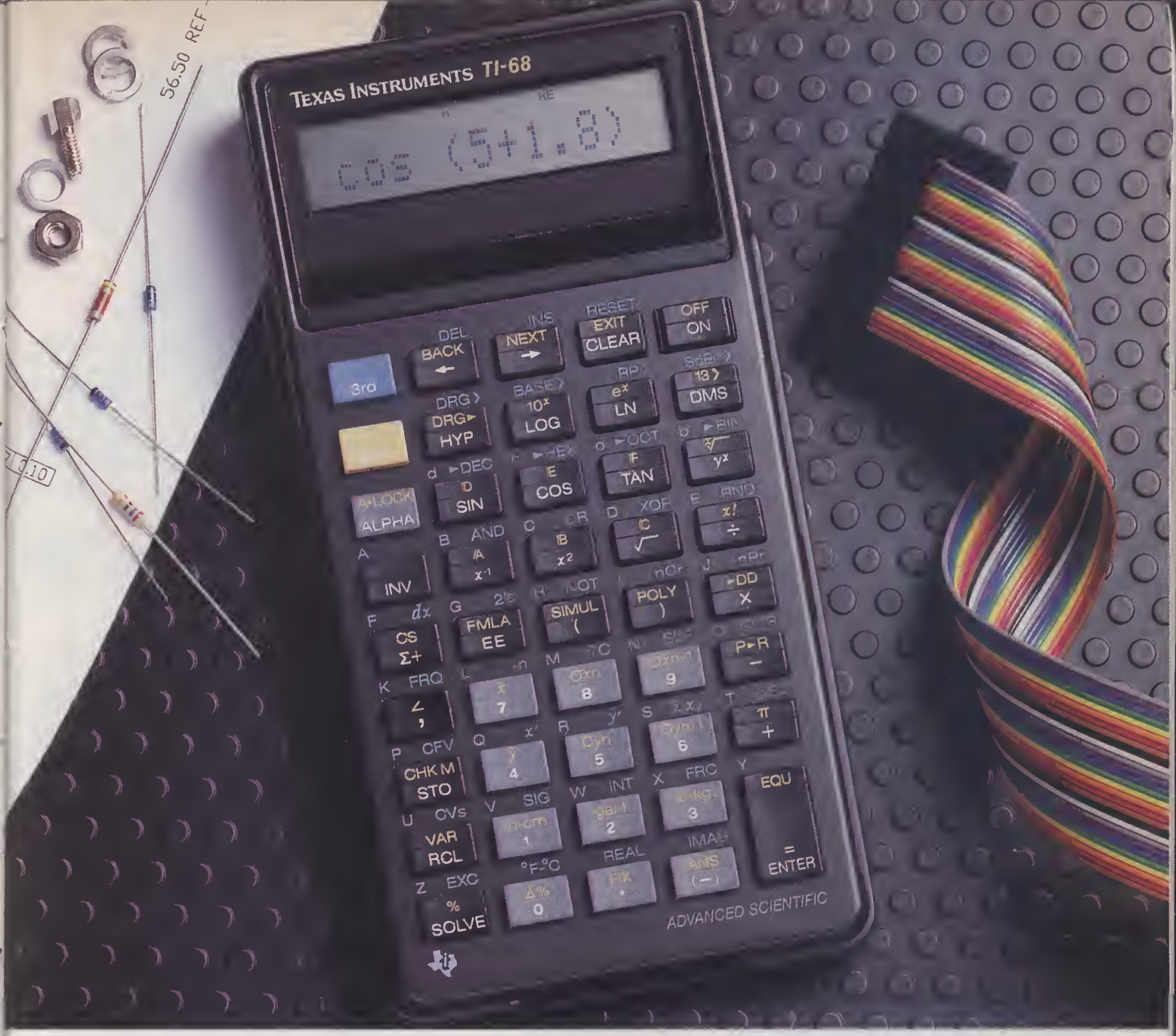
Ashley's final comment about (time-varying) electric and magnetic fields being "essentially independent of one another" reminds me of a voltmeter (not an electrometer) with an infinite impedance, one drawing no current, that is, a voltmeter with one open lead.

Leon W. Zelby
Norman, Okla.

Ashley's response, "There is no significant radiation of electromagnetic waves by 60-Hz power lines," made me think of a unique experience I had several years ago in a hot air balloon.

My pilot pointed out a power line ahead over which we would soon pass and commented that, for reasons he could not explain, it would cause a shift in the direction

(Continued on p. 18)



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TEXAS INSTRUMENTS

Circle No. 24

Forum

(Continued from p. 16)

of our course. We were floating northward at about 5 m/s (10 knots), while the power line ran east and west. We were about 60 meters above the line, as I remember.

As we started over the line there was suddenly a distinct pull on the gondola toward the east, and our course changed toward the northeast until we had passed over the line. We then resumed our drift to the north.

I attributed the pull to the generation of magnetic fields in the metal propane tanks in the gondola and being coupled to the electromagnetic field of the power line. (It was a three-phase 60-Hz transmission line supported by pairs of wooden poles.)

I am sure this does not fall into Ashley's intended meaning of "significant radiation," but it was at least interesting to this retired electrical engineer.

Tate B. Collins
Lawrence, Kan.

A current color code

One of my students here at Tulane University suggested an updated color code: Bad bolsheviks resist old Yeltsin gladly, but Vladimir goes willingly (or, if you prefer, guns wildly).

Cedric Walker
New Orleans, La.

Corrections

On p. 30 of the September issue, the photograph should have been identified as a TRC-170 (Track 170) Tropospheric Scatter Wideband Radio. This system provides digital wideband circuits for up to 250 km (over-the-horizon microwave).

On p. 56 of the issue, on the sixteenth line of the second column in the box, the paragraph number should have been 14.

On p. 34 of the October issue, the 800 telephone number for Trimetrix should have been 800-548-5653. —*Ed.*

Readers are invited to comment in this department on material previously published in *IEEE Spectrum*; on the policies and operations of the IEEE; and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial issues.

Contacts: Forum, *IEEE Spectrum*, 345 E. 47th St., New York, N.Y. 10017, U.S.A.; fax, 212-705-7453. The Compmail address is ieeespectrum. The computer bulletin board number is 212-705-7308 and the password is SPECTRUM; for more information, call 212-705-7305 and ask for the Author's Guide.

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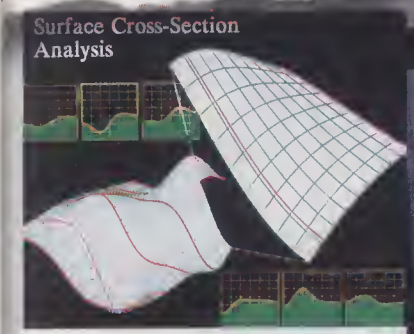

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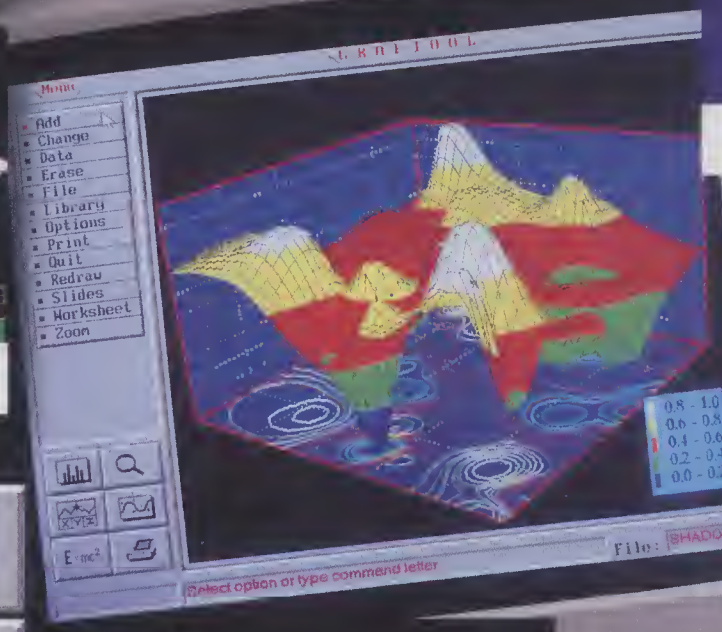

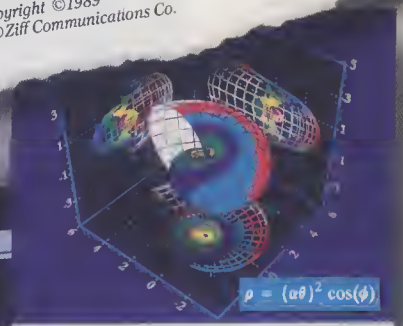

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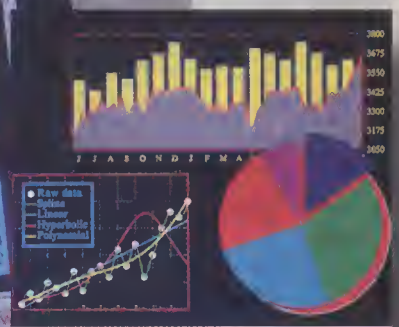

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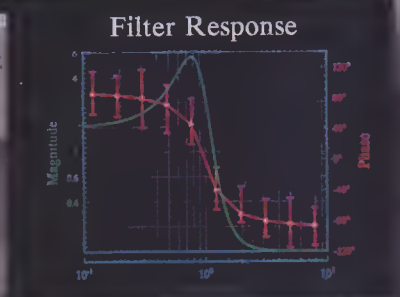

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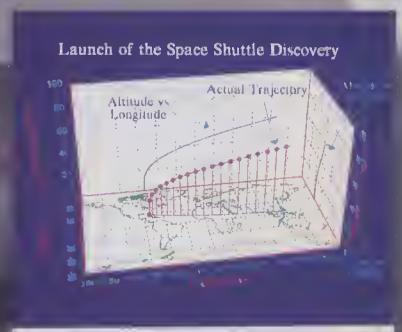

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THE ART OF ELECTRONICS
Horowitz and Hill

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The thoroughly revised and updated *Second Edition* of the hugely successful *The Art of Electronics* has already sold more that 45,000 copies in 18 months. This book is widely accepted as the singlemost authoritative text and reference book on analog and digital electronic circuit design. Responding to rapid-paced developments in the electronics industry, the completely new edition is 80% larger than the first edition and incorporates a large number of new and revised topics. The extensive practical advice and handy tehniques and tricks contained in this book make it indispensable to anyone whose research or experiments require some electronics.

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- useful subcircuits such as followers, switches, current sources, current mirrors, differential amplifiers, push-pull, cascode
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Cambridge University Press

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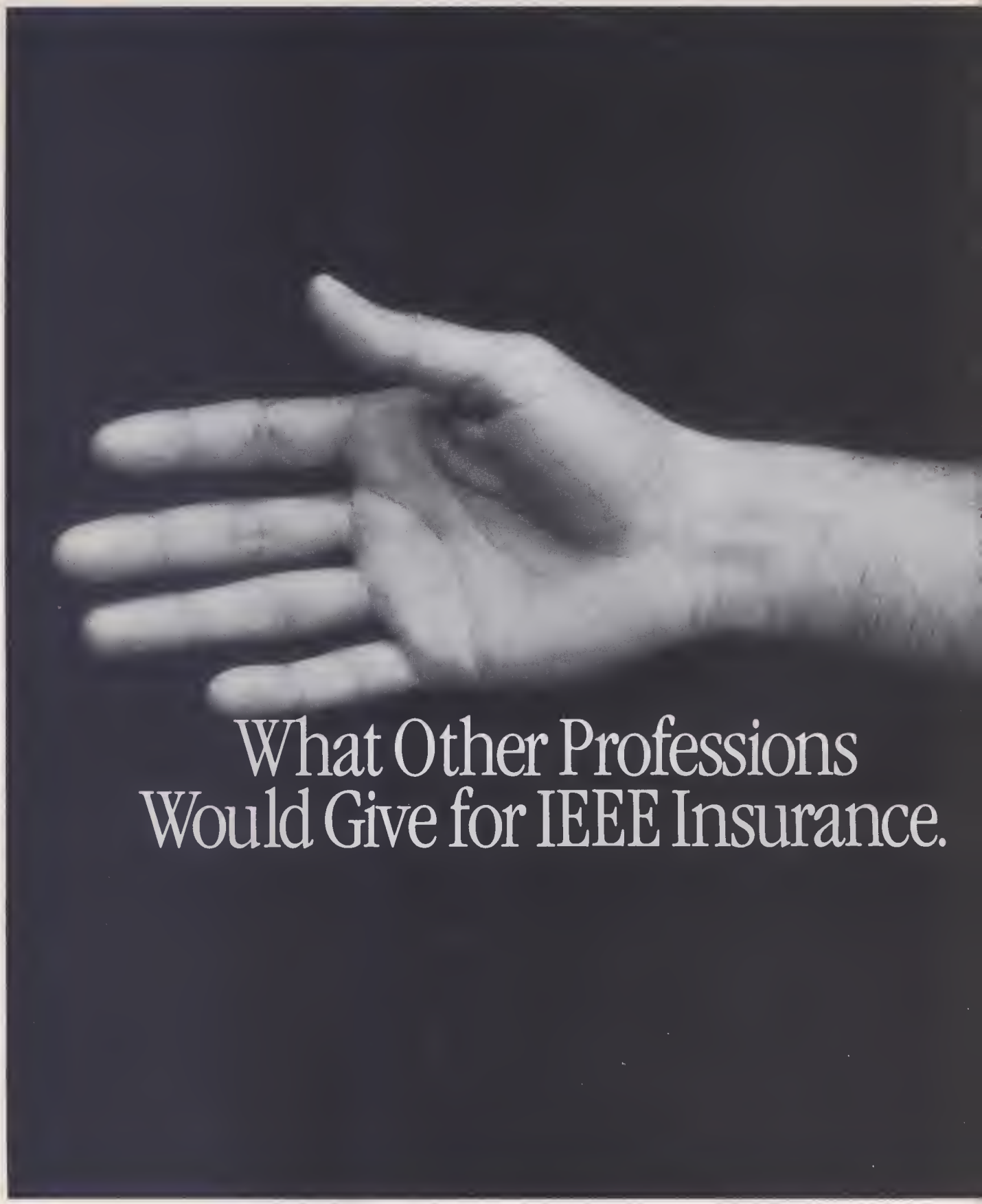

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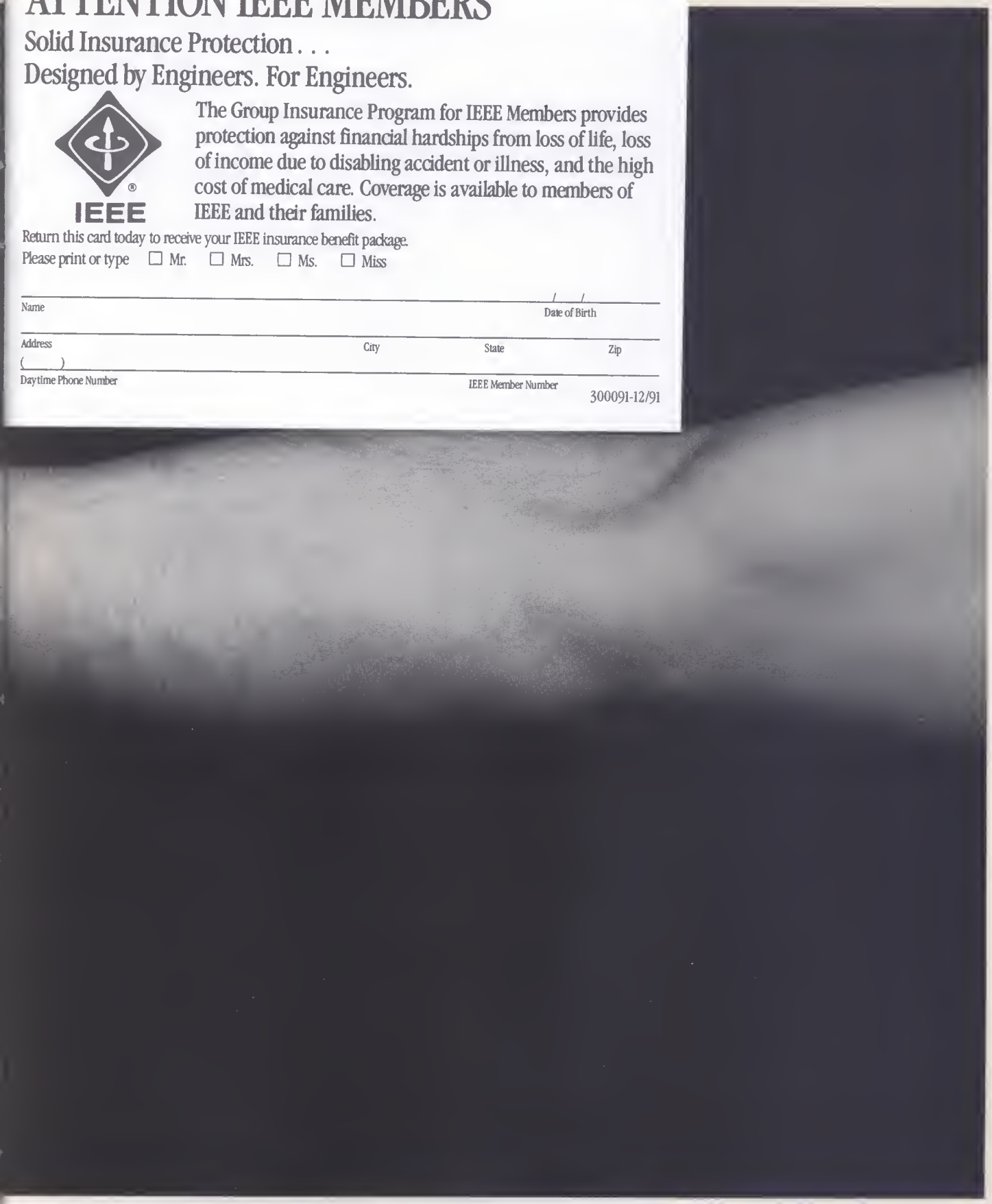

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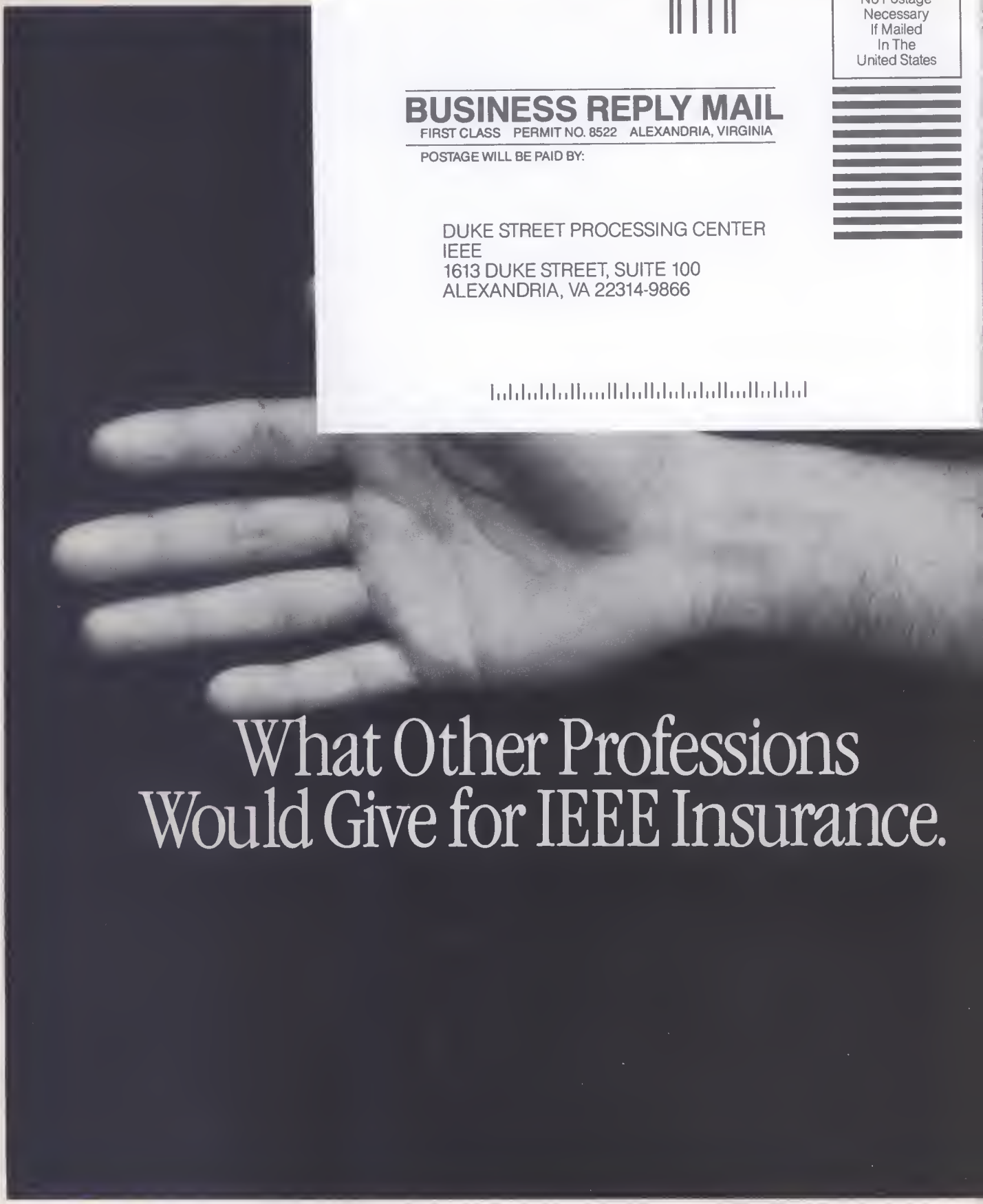

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Careers Conference Focuses on "Change & Competitiveness & Careers"

IEEE United States Activities held its Seventh Biennial Careers Conference in Denver, Colorado, on October 10 and 11, 1991, with more than 100 engineering managers, human resource professionals, consultants, and academic researchers in attendance. The conference sessions focused on such topics as upgrading professional careers, actions for competitiveness, improving career conditions and career satisfaction, and management policies affecting careers.

IEEE President-Elect Merrill W. Buckley, Jr., and Eve Majure of the American Electronics Association were keynote speakers. Buckley addressed "Career Issues As Seen By Engineers," and Eve Majure spoke on "Career Issues from Industry's Perspective."

Copies of the Conference Record are available from IEEE's Service Center at a cost of $20 for members and $25 for non-members, plus tax and shipping. To order, call (800) 678-IEEE and request IEEE Catalog No. UH0190-9. ✦

Foreign Investment in the United States: Unencumbered Access

Is foreign investment snatching up U.S. technology, endangering national security, and depriving IEEE members in the United States of jobs? Linda Spencer, author of an Economic Strategy Institute (ESI) study, *Foreign Investment in the United States: Unencumbered Access*, addressed these questions for members of IEEE-USA's Technology Policy Council, which is developing a position on these issues.

Spencer's study documents the U.S. Government's lack of oversight of foreign investments and purchases of economically and militarily critical U.S. companies. Despite passage of a 1988 legislative mandate to monitor investments in industries with national security implications, the Administration has reviewed only twelve such investments and halted only one to date.

Calling for increased Congressional oversight, the study outlines recommendations for comprehensive foreign investment legislation. For more information, contact Linda Spencer, Economic Strategy Institute, 1100 Connecticut Avenue, N.W., Suite 1300, Washington, D.C. 20036; or call (202) 728-0993. ✦

Updated Employment Guides Available

IEEE-USA is publishing two updated editions of its popular two-volume *Employment Guide for Engineers and Scientists*. This practical guide to finding or changing employment is put together by IEEE-USA's Employment Assistance Committee. One edition is specifically written for engineers and scientists who have employment experience. Containing information on salaries and solid advice on conducting a job search, this edition also provides assistance in coping with job loss, writing resumes, working with employment services, networking with colleagues and friends, interviewing, evaluating the compensation package, and knowing your legal rights in the employment process.

An alternate edition is written for students and contains basic information about how to conduct a job search. Special features include a list of the 50 most-asked questions during a job interview.

The companion volume to both editions is a *Directory of Employers of Engineers*. Listing hundreds of companies by state, the *Directory* includes telephone numbers and contact persons.

IEEE-USA provides complimentary copies of the *Guide* to unemployed U.S. members above student grade. Put your request in writing, including your member number, and mail it to the IEEE-USA Office in Washington, D.C. Both editions are also sold through IEEE's Service Center at a cost of $14.95 to members and $19.95 to non-members, plus tax and shipping. To order, call (800) 678-IEEE and request IEEE Catalog No. UH0186-7 for the experienced engineer edition or UH0188-3 for the student edition. ✦

That Volunteer Deserves A Medal!

How many times have you thought that IEEE-USA volunteers deserve some sort of reward for all the work they do to promote professional activities? Well, here's your chance to make that happen. Nominations for the 1992 United States Activities Board (USAB) awards are now open.

Nomination forms and further information are available from the IEEE-USA Office in Washington, D.C., where completed forms should be returned by March 31, 1992. ✦

Circle No. 38

Long-Term Health Care Insurance *Available to Members*

Many members know that the Institute has approved a number of insurance programs as a service to U.S. members, but they may not realize how important the long-term health care plan is to their future security. This plan helps protect a lifetime of savings from the potentially devastating financial consequences of an extended nursing home stay.

IEEE's plans are offered by sound insurance companies through an administrator that has served IEEE for the past 30 years. A group of volunteer members who comprise IEEE's Individual Benefits and Services Committee (IBSC) oversees the program.

According to IBSC, long-term care coverage is often neglected, although the need for nursing-home care and the cost of it continue to increase. Insurance of this kind is not usually part of a retiree's benefits, and many people are surprised and dismayed to learn that Medicare supplementary insurance plans don't provide this coverage. Currently, Medicare itself provides only "skilled" nursing—care that must be provided by a skilled health care practitioner—and only for a limited time.

IEEE's Long-Term Health Care plan assures quality care at affordable rates. The plan covers all levels of care, whether at home or in a nursing home, with a daily cash benefit and a duration you select, depending on which options you choose.

For detailed information, contact the Administrator, Group Insurance Program for IEEE Members, 1255 23rd St., N.W., Washington, D.C. 20037. In the Washington area, call (202) 457-6820, or call toll free, (800) 424-9883. ✦

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IEEE-USA Launches Legislative Initiative
to Aid U.S. Competitiveness

IEEE-USA's Committee on U.S. Competitiveness has increased activity to encourage Federal Government action and other efforts to improve the competitive position in today's global economy. Competitiveness issues are wide-ranging, involving engineering design and manufacture, education, government R&D policies, antitrust laws, and cost of capital for manufacturing facilities. From an employment standpoint, competitiveness problems are particularly important to electrical engineers—if U.S. industries do not prosper, neither will the careers of IEEE members.

Action on Capitol Hill

IEEE-USA volunteers testified this year in favor of S. 272, the High-Performance Computing Act of 1991. The bill provides for a coordinated Federal research program ensuring continued U.S. leadership in high-performance computing.

Former IEEE President Charles A. Eldon, a member of the Competitiveness Committee, testified before a House Subcommittee on Technology and Competitiveness. Stressing IEEE-USA's concerns that the United States stay competitive in the field of microelectronic components, Eldon also discussed decreases in U.S. productivity, problems in the U.S. education system, the lack of engineering education in manufacturing technology, and the need for industrial consortia.

Dr. Frank Pittman, Jr., a member of IEEE-USA's Engineering R&D Policy Committee, testified before the House Ways and Means Committee during Hearings on tax policy and U.S. competitiveness. He specifically recommended R&D tax credits, preferential treatment for capital gains, and favorable treatment for industry-university cooperative projects.

IEEE-USA is also considering drafting legislation to create a Federal enterprise that would provide low-cost capital for manufacturing facilities. Such an enterprise would be able to obtain private funds at low rates, because of implicit Government guarantees and access to funds not otherwise available to private interests.

Competitiveness Booklet Published

The Competitiveness Committee has produced a booklet, *How the United States Can Compete in the World Marketplace,* which was sent to IEEE volunteers, to Congress and the Administration, to other associations, and to approximately 1,500 chief executive officers of companies employing IEEE members. IEEE members can obtain a copy of the booklet by writing to the IEEE-USA Washington Office.

Circle No. 39

How to Help IEEE-USA's Competitiveness Effort

Members of Congress respond to their constituents. IEEE has nearly 250,000 U.S. members, and the Committee on U.S. Competitiveness would like your help. If you are willing to join this effort by writing or visiting your U.S. Representatives or Senators or their staff members to discuss competitiveness issues, please contact the IEEE-USA Office in Washington, D.C. ✦

Circle No. 40

IEEE United States Activities
Announces the 20th Annual Competition for
1992-1993 Congressional Fellowships

PROGRAM: Electrical and Electronics Engineers and Allied Scientists are competitively selected to serve a one-year term on the personal staff of individual Senators or Representatives or on the professional staff of Congressional Committees.

PURPOSE: To make practical contributions to more effective use of scientific and technical knowledge in government, to educate the scientific communities regarding the public policy process, and to broaden the perspective of both the scientific and governmental communities regarding the value of such science-government interaction.

CRITERIA: Fellows shall be selected based on technical competence, on ability to serve in a public environment, and on evidence of service to the Institute and the profession. Specifically *excluded* as selection criteria are age, sex, creed, race, ethnic background, and partisan political affiliations. However, the Fellow must be a U.S. citizen at the time of selection and must have been in the IEEE at Member grade or higher for at least four years.

AWARDS: IEEE-USA plans to award at least two Congressional Fellowships for the 1992-1993 term.

APPLICATION: Further information and application forms can be obtained by calling W. Thomas Suttle, (202) 785-0017, at the IEEE-USA Office in Washington, D.C., or by writing:

Secretary, Congressional Fellows Program
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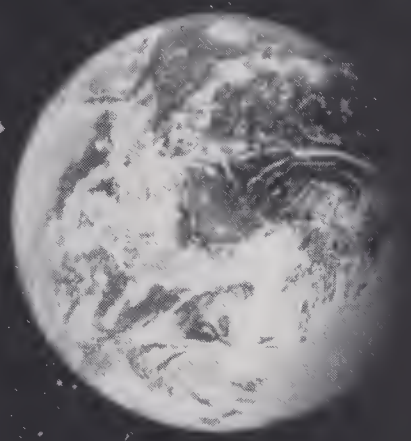

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Circle No. 43

Program notes

Maybe your PC can tell you something

In the movie "Star Trek," Command Data is a silicon-based lifeform that speaks, learns, and feels almost like the carbon-based life forms who crew the Enterprise. Real-world computers as yet can only talk, and not too well at that. Still, even desk-top models can now produce limited speech without adding hardware if they use software like Monologue from First-Byte, Santa Ana, Calif.

Speech generation techniques parallel three methods of teaching children to read—rule based, table-based, and mixed-mode. The rule-based method corresponds loosely to the phonetic method of teaching reading: a set of rules defines algorithms for converting written word fragments into spoken word fragments that are strung together to produce spoken words. Table-based speech generation mimics the see-and-say method of learning to read: a look-up table defines an algorithm for converting each written word into a spoken word. Mixed mode resembles the empirical approach to reading taught in most schools, combining rule-based speech generation with table-based speech generation for exceptional words.

The three techniques have different areas of application. Table-based speech is useful when an industrial controller must pronounce a few words correctly; the talking automated teller or the arcade game are examples. Rule-based speech is appropriate when an industrial controller must pronounce many different words, as must, say, the low-cost hard-copy reader and the home game computer. Mixed-mode speech is suitable for a 16- or 32-bit microprocessor that must pronounce many words accurately in applications like industrial computers and high-performance hard-copy readers.

FirstByte's Monologue is an example of low-cost, mixed-mode speech generation software for IBM-compatible personal computers. It is a DOS-based terminate-and-stay-resident (TSR) program loaded into memory before it is needed. When activated from the keyboard, it reads screen text selected by cursor or mouse. When linked with a Basic, Pascal, or C program, it reads text written to the screen.

The speech it produces is recognizable and obviously machine-generated when emerging from the speaker on the PC, but very lifelike when uttered by a speech accessory like The Speech Thing from Convox. *Contact: FirstByte, 3100 South Harbor Blvd., Suite 150, Santa Ana, Calif., 92704; 714-432-1740;* **or circle 101.** *For more on The Speech Thing, contact Convox, 675 Conger St, Eugene, Ore. 97402; 503-342-1271;* **or circle 102.**

Renovating old code

Programmers often inherit hard-to-handle code. It may violate all the syntax rules, being so tangled as to warrant the name of spaghetti code; or it may be written in a dialect or language not in use.

Modifying such code is always difficult. Small changes in spaghetti code can cause unwanted alterations in other parts of the program. Minor updates to programs written in unusual dialects or unfamiliar languages can become major projects.

One way to simplify modifying older code is to write or buy programs that automatically reformat code and translate it into another language. Many commercial and also public domain programs convert Fortran spaghetti code, for example, into structured Basic, C, or Pascal code. Simpler products restructure the code and translate it into a modern dialect of the language. The best programs restructure the code and translate from one of several dialects to the others, giving the programmer the freedom to program in whatever dialect is appropriate

(Continued on p. 44)

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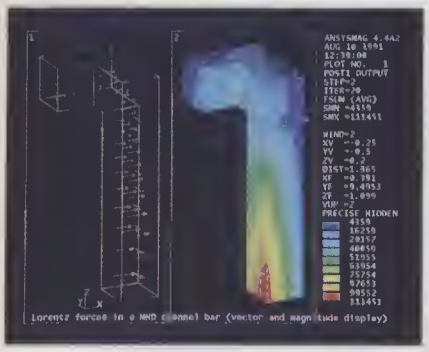
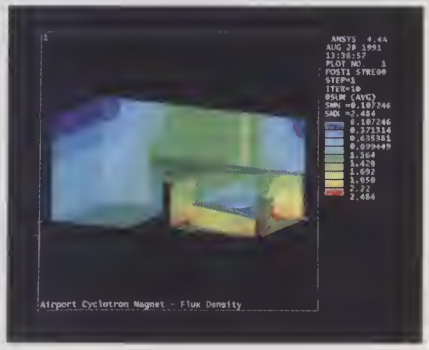
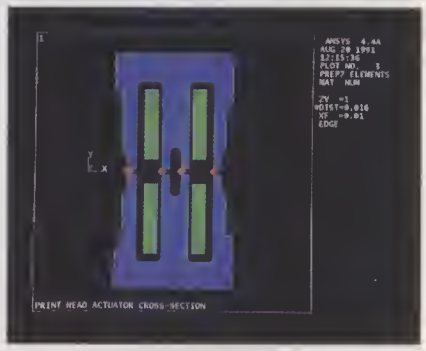


ANSYS magnetics was used by Stone and Webster Engineering Corporation with MIT Plasma Fusion Center to analyze the conductors, iron mass, and field in a MHD channel. Displayed are the Lorentz forces in a conductor.



Magnetic field analysis for a cyclotron magnet design was performed by the National Superconducting Cyclotron Laboratory, Michigan Stote University, using ANSYS magnetics to determine flux density levels.



A printer head linear actuator device was modeled by IBM Corporation to evaluate normal end axial forces on a sliding armature situated between two stotors.

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DECEMBER 1991 Volume 28 Number 12

Nurturing the open mind

Two characteristics of the innovative mind consistently emerge from interviews with engineers whom their colleagues agree possess innovative genius. First is an open mind. And the second is persistence in the face of discouragement. The two are related. Great innovators intrinsically enjoy their work, so there's little need to prod them to keep an open mind. Not fearing failure, they have little hesitancy in trying something more conservative engineers might eschew.

Not everything works, but that's part of the process. Thomas Edison's experimentation is a classic example. Like some fine artists who say, "You've got to draw it wrong before you can draw it right," innovators in electrotechnology observe that you'll never know if it works if you don't try it. When an experiment fails, they learn from it.

As persons of high confidence and, usually, of high emotional stability, innovators are apt to pursue a case on its technical merits, dismissing or bypassing impediments raised by bureaucracy while heeding, but not being deterred by, colleagues' criticisms. At the same time, as psychologist Michael Maccoby points out in his analysis in this issue, innovators are sensitive to the larger environment that involves economics, need, and acceptance of a product in a cultural context. Otherwise an idea could remain a mere unapplied invention, as opposed to a truly worthy innovation.

At some point, when a path seems clear or an experiment seems worth doing, the successful inventors pay little heed to discouraging environments. Many recall respected colleagues telling them something could not work, just prior to their doing it. Corporate managers may take away funds, but somehow the work is bootlegged.

Many of the great innovators do not see their role as supporting a corporate "team," but, in fact, as independent thinkers or devil's advocates who may often find themselves moving at a sharp angle to a company's current themes. Often they appear uninterested in an organization's internal politics. Yet if the bureaucracy becomes too imposing, they have no qualms about moving to a friendlier environment.

Successful innovators follow different patterns of invention. A common characteristic, however, is the ability to step back and view the larger picture. Some refer to it as a systems outlook. Many innovators see it as the stage that requires more patience and contemplation, so as not to preclude any options through premature embarkation on one path.

Some innovators, in fact, seem most comfortable working in the systems definition stage, leaving the details of implementation or options studies to other members of the organization. Sony Corp.'s cofounder, Masaru Ibuka, and California Institute of Technology's John Pierce may fit this pattern. But some innovators do not begin with the systems phase. James Blinn, an animation specialist, feels more comfortable dealing with some details first, rather than starting with

an overview of the problem—but from that point on he iterates between the two.

The notion that an innovative idea may strike like lightning is rejected by most inventors in our field. It is mythical, they say, like overnight stardom. Years of methodical hard work are the traditional prerequisites.

One framework for studying the innovative process has been proposed by W. Bernard Carlson and Michael E. Gorman, of the University of Virginia, who postulate that both mental and experimental models are important elements. They view the process as one in which the innovator, prior to synthesizing an invention, compartmentalizes experiential knowledge into "slots." This fits well with a process alluded to by Jacob Rabinow, who describes it metaphorically. When looking for a solution, Rabinow says, one figuratively puts all the things one knows on cards and throws them into the air. As they hit the floor in interesting combinations, he says, new insight may be revealed.

It is probable that among the elements of intelligence slotted into the pigeonholes of the inventor's mind are various learned shortcuts that can be appropriately recalled and reused. It may in part be the application of these shortcuts, and their synthesis with one another, that seems to others to represent "strokes of genius."

Or does genius go beyond even that? Self-taught English mathematical physicist Oliver Heaviside's audacious use of physical or intuitive arguments to establish mathematical results is reported to have driven the pure mathematicians among his contemporaries to near apoplexy. To outsiders, methods like Heaviside's are dazzling—like a mountain goat's ballet as it leaps from one slender outcropping to another with grace and confidence, and with little evident forethought.

In the end, some managers suggest, innovation is but one part of engineering, and if every engineer were to possess the degree of inventive genius enjoyed by the subjects of *IEEE Spectrum*'s interviews in this issue, who, they ask, would do the routine engineering.

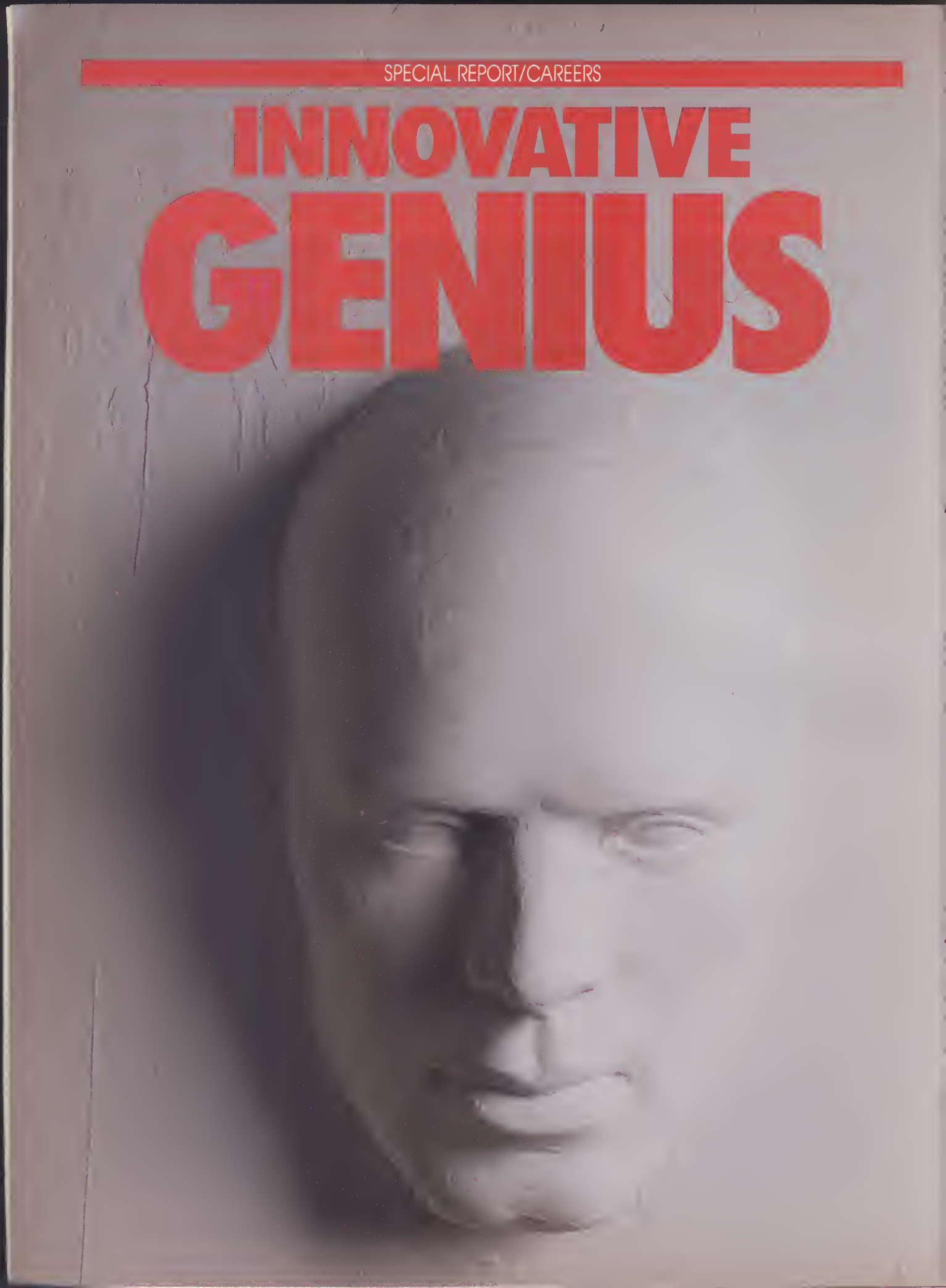
Even so, there are many of us who believe that we occasionally exhibit traces of the innovator's brilliance, and that nurturing those personal and environmental characteristics that support innovation is in the best interests of good engineering.

Spectrum's editors are indebted to the colleagues of those masterful innovators who participated in this special report for their help in choosing them and for their useful observations on the process of innovation; to Michael Maccoby for his insightful analysis that accompanies the report; and to the IEEE Foundation and the IEEE Life Member Fund for assistance in funding its publication.

Donald Christiansen

SPECIAL REPORT/CAREERS

INNOVATIVE GENIUS



The innovative mind at work

Some engineers seem to transcend change; they move effortlessly from one technological advance to another, making their mark and enriching the field as they do. IEEE Spectrum *asked a few such people to tell us about their backgrounds, achievements, work habits, and feelings about their own creativity and gifts for innovation.* Spectrum *also asked psychologist Michael Maccoby to analyze the responses for common and divergent characteristics in the hope of resolving our ideas about the nature of innovators.*

At Spectrum*'s request, prominent IEEE Fellows nominated many candidates—men and women from around the world. With great difficulty, the eight covered here were picked from the list according to these criteria: they have made contributions over many years, they are highly regarded in their fields, and they represent a spectrum of backgrounds.*

Maccoby's analysis is based on the complete texts of Spectrum*'s interviews. The profiles are distillations of those interviews.*

Innovators delight in exploring unknown territory; their reward is simply the work itself—indeed, work for them is play

Plato writes that man is closest to God when he is playing. While we work out of necessity, for survival, play is an expression of freedom. Through play, we discover, innovate, and express ourselves. As infants, we play at peek-a-boo to master feelings of abandonment. As small children, we make "What if?" excursions into fantasy and begin to play games that require discipline, strategy, and tactics.

The disciplined play of the innovators interviewed by *IEEE Spectrum* editors employs the tools of science to understand how things work and to build on that insight by inventing. As Carver Mead put it, "Sometimes you can't prove it. You need to do it." In the Platonic sense, these innovators have become God's colleagues in creating the world. As Charles Townes reflected, "I never felt that I really worked at anything. It's all play."

Perhaps it would take a different kind of innovator to understand them fully—to comprehend their psychology and mode of thinking. Doubtless, genetics plays a major role, and so it would seem from their family histories. Jun-ichi Nishizawa's father, now aged 98, was dean of the faculty of technology at Tohoku University and his younger brother is now professor of metallurgy there.

Townes's older brother was a well-known entomologist, and his other siblings are teachers and professionals. Rabinow's older brother was also an electrical engineer. And so on. Although the interviews do not emphasize childhood experiences, one gets the sense of families that support learning and curiosity. The spirit of play is not stifled by poverty, fear, or demands that these innovators become early over-achievers.

How do their minds work? In particular, how do they choose problems to think about? John Pierce said, "I see something that ought to be within my grasp, but it isn't, so it seems worthy of pushing on."

Michael Maccoby The Maccoby Group

These innovators enjoy grappling with problems, especially in untrodden areas. Townes said that he stays in a field until it is no longer "interesting," meaning it offers nothing new to discover. For Mead, inventions are things that "just had to be done." He admits that "something is bothering me because it isn't understood." He feels "there must be a better way."

A difference between innovators and inventors is that while the latter contrive new devices or methods that may or may not be adopted, the innovator changes things on a broad front. The innovators, by definition, choose big problems with large implications. Pierce designed telecommunications satellites, Townes invented the laser, Mead is determined to transform the programming industry, and Nishizawa wants to revolutionize power electronics the way he changed telecommunications with fiber optics.

The bigger the innovation, the more resistance and disbelief it provokes from others. Genius innovators see things in ways that may not make sense even to distinguished colleagues. Mead cites British writer Arthur Koestler's *The Act of Creation* on benefits of placing a problem within a totally different conceptual space. But this is only a benefit if one has been deeply immersed in a problem and has the intellectual power to put things together in new ways. Pierce said, "As you think about a problem, you fill your mind with ideas about it, but the solution is apt to come rather suddenly."

When I studied technical innovators for my book *The Gamesman* (Simon & Schuster, New York, 1977), I used the Rorschach test. I found that when asked to describe what they saw in the inkblots, the most innovative engineers and physicists saw the blob first as a whole and then delineated details. In contrast, many engineers first look for clearly recognizable details and then may try to put them together.

While *Spectrum*'s innovators did not take Rorschach tests, most of them said they first try to see the problem as a whole and then work on the details in relation to the whole. Masaru Ibuka put it this way: "I think over the issue I am working on and wait until I get a vision that illuminates its overall nature. Then, I communicate this to my staff and we work together to set a clear direction for its solution. We explore all the various possible alternatives."

Although as children they were tinkerers, as grown-ups the innovators tend to grapple with problems that have broad implica-

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tions. These problems are not merely technical, but have to do with enhancing the human capacity to communicate and create. Nishizawa sees the meaning of his work as improving "the living conditions of every human being." He notes that this mission has developed from a nationalistic drive: "We Japanese do not have many natural resources, even food, so we should invent and develop new technologies."

James Blinn invents his high-technology animations in order to teach others about science, while Mead connects his inventions to the world of business. For him, creativity includes not only science and technology but also the need to transform the market. Pierce believes that "peace and prosperity depend on communications." He is turned off by the idea of space travel: "I didn't believe man would go up into space and do anything useful, and I don't think they have!"

The innovator has a systems mind, one that sees things in terms of how they relate to each other in producing a result, a new gestalt that to some degree changes the world. The goal of the system depends on the breadth of one's thinking. For example, one can think about a car in terms of all its parts working together to make it go. Or one can think of it as a dynamic element of a transportation system depending also on highways, fuel, and so on.

In contrast, most engineers do not think in systems terms. They are concerned about designing a good piece-part, like a clutch. The innovator goes beyond the invention to consider its impact on a larger system.

Once a new conception begins to develop, the innovators try out ideas with students and colleagues. Jacob Rabinow likes to "bounce ideas off people." John Cocke speaks of "playing off ideas." Writing an idea up is important for Pierce. However, they do not expect immediate agreement or acceptance. Townes related how I. I. Rabi, the Nobel physicist, disparaged his new ideas. Nishizawa pointed out that his inventions in fiber optics antedated by 10 years Japan's ability to make use of them.

It is significant that, although they work in a society known for pressures to reach consensus, the Japanese innovators march to a different drummer. "I never give up [just] to obtain agreement," stated Nishizawa. And Ibuka said much the same: "I do not take any heed of negative opinions. I just go about my work in earnest."

Many people do not learn from negative instances. Failure, or the inability to find confirmation of one's hypotheses, causes an emotional letdown, disappointment. Research shows that in these cases, information that might be there to learn is ignored.

The innovator, on the other hand, finds disagreement an important stimulus to problem-solving and is not put off by failure. Rabinow talked about the right to fail without feeling a failure. Cocke said, "It is a pleasure when you are wrong, because that

(Continued on p. 35)

JACOB RABINOW:
326 patents and counting

To Jacob Rabinow, inventions are "an art form like all things that are created in the depths of the human brain"—and an antidote to an unusually "low threshold of pain" for the world's imperfections. He ought to know. In both number and breadth, his patents testify to an extraordinary inventiveness. Rabinow holds 226 U.S. patents and about 100 in other countries. But those 100 he does not count because, except for one in Japan, they are duplicates of U.S. patents. He also emphasizes that many of them are "cluster" patents—awarded for inventions that were offshoots of his earlier inventions.

The list includes safety mechanisms for bombs and rockets, a gyro control for guided missiles, a servo-driven straight-line phonograph arm, an automobile headlight dimmer, an automatic regulator for clocks and watches, the magnetic particle clutch, a pick-proof lock, reading machines, a postal letter-sorter, and the first magnetic-disk file for computers.

When *IEEE Spectrum* talked to him in his home in Bethesda, Md., Rabinow was recovering from a cataract operation. Despite that and his 81 years, he was eager to talk about inventing and showed us many original models of his work. Most of the papers related to his inventions he donated to the National Institute of Standards and Technology (NIST), where he spent much of his career. (He still works as a consultant for NIST a few days a week, mainly in helping to evaluate ideas submitted to the institute's Office of Energy Related Inventions.) Other papers he has given to the Smithsonian Institution, Washington, D.C., which features models of some of his inventions.

Inventing for Rabinow is done for the fun of it, because he needs something for himself or for his friends, or to solve a problem. He considers it a challenge. "You want to do something better than it has been done before, or that has never been done before," he said. But to be commercially successful, an invention needs to be "five or 10 years ahead of when anyone would have a need for it."

There is no formula for inventing, in Rabinow's opinion. He attacks anything that interests him, analyzes it, and looks for a way to solve it. He savors solving problems. "It's an ego trip," he told us, adding that "it's easy to be clever when no one else knows anything about the problem, as in new ordnance during World War II."

A negative reaction does not bother him. He just shrugs and tries to look at the situation in another way, or else drops it. "Because you think you're good, you have an absolute right to an occasional failure," he said. "Don't expect to be successful all the time."

Rabinow told us that his early inspiration came from Jules Verne, whom he read as a child in Russia, "fascinated by the technology described."

The son of a shoe manufacturer, Rabinow was born Jan. 8, 1910, in Kharkov, Russia. Four years later, his family moved to Kustanai, Siberia, where his father had another factory making shoes to order. But in 1919, because of the political unrest in Russia, they fled to China, where his father died soon after. In 1921, Rabinow, his mother, and older brother then moved to the United States, settling in Brooklyn, in New York City.

At Brooklyn's Thomas Jefferson High School, from which he graduated in 1927, Rabinow admits he was a "good" student. After working as a salesman, a radio installer, and a repairman for a radio store on Cortlandt Street in Manhattan, he entered the City College of New York (now City University) in 1928. There, he said, he was at best an average student—except in purely technical subjects. He received a B.S. degree in engineering in 1933 and stayed on to earn an E.E. degree in 1934.

Few jobs for engineers were available and Rabinow did not find one until 1938—as a mechanical engineer at the National Bureau of Standards (now NIST). He began by calibrating water current meters used to determine how fast a river was flowing. Realizing

the meters were inaccurate, he asked leave to redesign them. That sparked his lifetime of innovating. (An earlier attempt when as a child he had "invented" a rock catapult had ended in disappointment when he learned it had been developed 2000 years before by the Romans, who called it a *ballista*.)

During World War II, his innovative work on proximity fuzes and other ordnance problems at the bureau won him the position of division chief and a series of awards and honors. Between 1954 and 1972, he worked in industry, even setting up his own company, Rabinow Engineering in Rockville, Md., in 1954. The following decade Rabinow considers his most fruitful because "I had the money then to do what I wanted and it was a lot of fun." But in 1964, when his company became part of Control Data Corp., "I couldn't fool around anymore," he said.

After a stint as president of another company, Rabco Inc., which was later acquired by Harmon Kardon Corp., he rejoined the National Bureau of Standards and became chief research engineer of the National Engineering Laboratory. He retired from full-time employment there in 1975.

Rabinow revealed that his work habits include standing or sitting on a tall stool (he likes higher-than-normal work surfaces). When he had his own company, he would as a rule quit at five o'clock. Enough was enough, he felt, and he does not believe in rushing an invention. But sometimes, when he was hot on the trail of something, he would work well into the night.

In the initial stages of innovating, he likes to work with others, bouncing ideas off them. He has never had an invention stolen from him as a result of this idea-bashing, nor has he ever had a patent suit filed against him. He also enjoys communicating his ideas verbally to selected people and likes having technical people respect his work.

Flashes of inspiration come to him while shaving, driving, or partaking in other activities. Solutions are usually sudden in his case.

Luck played a big role in his success, he thinks, including having smart parents, having come to the United States, having gotten a good, free education and a job at the National Bureau of Standards, and having had brilliant and tolerant bosses. He disclaims any major failures, having dumped unworthy projects before they went too far.

Burnout has never troubled Rabinow when inventing, only at times when trying to sell his inventions. At present, for instance, he is tired of trying to interest anyone in the pick-proof lock he created.

In Rabinow's recently completed first book, *Inventing for Fun and Profit* (San Francisco Press, 1990), he recounts his career and explains how he came to invent specific devices. He also offers some thoughts on the process of inventing and pieces of advice to would-be inventors. Here are several:

- "The trouble with the word 'invention' is that it implies something fundamental or important, or something that people will use or buy. That is far from being the case. An inventor does many things for himself that are not important."
- "The ego, the challenge, the fun of solving a problem are very important to people like me, and I am sure this is true of most inventors."
- "I warn inventors that unless they make a very thorough search in the Patent Office and other literature, they should not waste much time or money. The chance of being original is very small."
- "There are at least two types of inventions. . .One creates a solution to a problem that is either recognized by many or that is presented to the inventor by outside sources. In the other type of invention, the inventor solves a problem because he or she imagines that something should be done, something that other people don't know needs to be done. Once it is done, the invention becomes needed. This is the case where invention is the mother of necessity."
- "I have no doubt that invention is a random process. It bothers people when I say that inventing is not done logically. . .If all inventions could be done by logical, rigorous procedures, we could program computers to do it."
- "In my opinion the process of invention is something like this: When one is looking for a solution—for example, how one should read printed characters—one figuratively puts all of one's information, all the things one knows, on cards and throws them up in the air. As the cards hit the floor one looks them over and sees if any of them together, in combination, make sense. Does the combination come up with something that one hasn't yet thought of—a new interesting combination? The individual items of the combination may be quite old."
- "Perhaps the real reason one invents is that one has a low threshold of pain—that I am bothered by things that don't work well, or things that work but that I think I could make work better. I am sure this is true of others. And like dope addicts, we know that the way to stop the pain is to invent a better way. It may never work and we may never use it, but the fact that we do it somehow or other reduces the pain and makes one feel well." —*Ronald K. Jurgen*

Jacob Rabinow with models of a few of the many inventions for which he holds patents.

James H. Pickerell

CARVER A. MEAD:
blending science and engineering

The hours after dawn are Carver Mead's time for innovating. Tucked away in a log cabin amid redwoods in the hills above California's Silicon Valley, or in his home in the Los Angeles canyons, Mead wrestles with ideas between sunrise and breakfast.

"Something that needs to be invented," he said, "starts as an emotional itch that you can't scratch, a vague sense of discontent with something that isn't understood."

"Then," Mead told *IEEE Spectrum*, "I become aware of a frustration with the existing way it's done, and for months in those early hours I'll struggle with the problem, even though often I can't quite see what it is. Then some morning it will go click, and I'll have an insight, which will take me a little ways. Then I'll get stuck again. Then there will be a more intense set of frustrated feelings, but usually what needs to be done begins getting clearer."

This is Mead's version of the creative process, a solitary struggle to be pursued "until reality intervenes." The phone rings, an appointment is scheduled, and it is time to go out in the world. The rest of the day Mead, a professor at the California Institute of Technology in Pasadena, spends meeting with students, consulting with companies, or trying out new ideas in the laboratory.

What he avoids early on, however, is discussing his struggle, because, he said, the only language for a problem already contains the traditional viewpoint and "if you use that language, you come up with the same answer everybody else has."

But Mead still requires regular contact with other scientists and engineers. He typically talks to people, rather than reading. "Without contact with a rich intellectual space, I would have been barren," Mead said. "I can't invent things from just zero. Inventing for me is putting together things that are from the milieu of people, ideas, insights, and ways of thinking that I collect."

That milieu has served Mead well in his innovative work in developing what is now called the MESFET (metal semiconductor field-effect transistor), in silicon compiling, and in artificial neural networks.

Sometimes, though, the milieu has failed him. Mead said he missed by a hair the Nobel Prize in physics awarded in 1973 for superconducting tunneling to Brian Josephson, Leo Esaki, and Ivar Giaever. Several years before Giaever performed his breakthrough experiment, Mead was looking for a metal with an energy gap above its Fermi level on which to perform tunneling experiments. Even though Mead's office mate was working with superconductors, Mead never connected them with the material he sought, and in the end dropped his search. "Even if you have the right idea and you see it clearly, you'll fail if you are missing a piece of the puzzle," Mead told *Spectrum*.

Raised as an only child in a house in the woods in Northern California, Mead attended grammar school at a one-, then later, two-room schoolhouse, where he was free to eavesdrop on all the lessons, not just concentrate on his grade level. He built things all the time, he recalls—from modifying scooters to make them easier to ride on hills to inventing an adjustable spinner for his fishing rod. From his earliest years he had access to information about electrical things from his father, who worked for a local power plant. An uncle introduced him to radio, with which he became fascinated. When he was 12, he recalls, a new neighbor arrived with ham radio gear and stacks of manuals that Mead explored. Armed with this new knowledge, he haunted war surplus stores and began building anything he could, getting a job at a local radio repair shop and later at a station in Fresno as a transmitter engineer.

At the urging of colleagues at the radio station, Mead changed his college plans—from dentistry at Fresno State to electrical engineering at Cal Tech. Receiving the B.S. in 1956, the M.S. in 1957, and the Ph.D. in 1959, Mead stayed on as an assistant professor and never left. "I'm a lifer," he told *Spectrum*.

Nevertheless being a lifer does not mean that Mead always remains in the ivory tower. "If you stayed there all the time," he said, "it would be deadly, because it is so insular. People just talk to other people in the field and often don't know what is going on in the real world."

To combat that insularity, ever since he was a graduate student, Mead has spent part of his time consulting with industry, plunging into the Silicon Valley corporate environment on Fridays and however much of the weekend is necessary. While he has played a part in launching a number of Silicon Valley start-ups—one of his earliest was Silicon Compilers in San Jose (1981), and his most recent is Synaptics Inc. in San Jose (1986)—he was never tempted to leave academia entirely. "It's too important for me to have a science base," he said. "Every company I've been associated with has to run so hard to stay good at what they're doing that they can't move on to new technology."

Blending basic science with developmental engineering has been a theme throughout Mead's career. His first realization that the underlying physics of a device and the circuit itself interacted in unique ways came in 1957, when he studied the work of Stanford University Professor John Linville, who had modeled the inner workings of a transistor.

"I used his method to figure out how a transistor would work when

Jon Brenneis

Carver Mead shows his design for a retina-emulating silicon chip.

switching large currents," Mead said. "It wasn't a big deal, but it was the first time I myself had figured out a new thing that had both circuits and physics in it."

From there, Mead began studying tunnel diodes, which had recently been invented by Japanese researcher Leo Esaki. For 10 years Mead tried to simplify the underlying theory of Esaki's discovery and to build various tunneling structures. Along the way, he invented several devices: one was a tunnel transistor, which never became a product because it was not as useful as regular transistors; another was what Mead called the Schottky barrier-gate field-effect transistor, now called the MESFET, which he built out of an as yet unexploited semiconductor material, gallium arsenide. The MESFET, completed in 1965, did not catch on for about 10 years; it is now used in satellite communications and ultrahigh-speed logic.

In 1968 Mead developed what some consider his most influential theory. Preparing for a talk on device physics, he began thinking about the scaling of semiconductor devices. The common lore at the time was that while manufacturing developments would allow for the doubling of the number of transistors on a chip every year, as devices got smaller and more tightly packed, power dissipation would go up till devices became too hot to work. The predicted feature-size limit was 10 micrometers.

Something bothered Mead about that theory, and when he worked through the problem, he concluded instead that, as devices got smaller and denser, they dissipated less power; the 10-μm barrier did not exist.

He began preaching this new doctrine throughout the semiconductor industry and, though initially he met with skepticism, he started a wave of activity.

He also launched himself into a new field. "I was [predicting] millions of devices on a single piece of silicon," he recalled. "If [so, doing physics was] the wrong end of the problem. The real problem was going to be that nobody had any idea how to design a thing with a million moving parts."

Mead knew that computers would be the answer. However, he know nothing about them beyond a smattering of the Basic programming language. "I had had just one course in symbolic logic as an undergraduate, and it was a humanities course," Mead said. Learning the new field was "excruciating," but "I couldn't help it; it had to be done."

In 1971, working with then-freshman Steven Colley (now president of NCube Corp., Beaverton, Ore.), Mead built his first silicon compiler for designing dense silicon chips. Continuing to work with the technology, he gave a short course on very large-scale integration (VLSI) design in 1976 at Xerox Corp.'s Palo Alto Research Center. That teaching prompted a project with Xerox researcher Lynn Conway: develop the idea of structured VLSI design into a book. *Introduction to VLSI Systems* (Addison-Wesley, Reading, Mass.) was published in 1979, and is still considered the basic text for the field.

With the publication of the book, the launching of a company (Silicon Compilers) to develop design tools, and the arrival of new players into the field, Mead felt he had contributed about all he could to VLSI design. He was also badly burned out, he told *Spectrum*: during the period of most intense work on the book, while keeping up with his students at Cal Tech, Mead had faced a number of personal setbacks, including a divorce and the deaths of both parents and a daughter. Then he walked through a glass window at a friend's house. To regroup, he retreated to his ranch in Oregon. When he returned to Pasadena, he decided to pursue a research interest that long had been in the back of his mind: neural networks.

Mead was first introduced to neural networks in 1968, when Nobel prize winner Max Delbrück asked for his opinion of a new theory in neurobiology—that a nerve membrane works like a transistor. Mead looked at the theory, then pronounced it "garbage." But he was intrigued enough to do some experiments and develop a theory that would work. Soon, however, the work in silicon compilers became "all absorbing," and he dropped his efforts in neurobiology, though throughout the next 10 years, he recalls, "this vague analogy kept running in my head, how the brain getting itself wired up is similar to what a chip compiler does."

Since 1983 Mead's research focus has been entirely on what is now called artificial neural networks. "Neural circuits are more exciting than anything I've done before, with, I think, much more far-reaching implications," he admits.

So far Mead and his students have developed chips that emulate the retina, which is expected to ultimately be useful for machine vision. Currently he is working on an artificial cochlea, and recently he designed a chip that can analyze a sound wave and "hear" a fundamental note missing from a harmony. His most exciting new projects are chips that learn from experience in real time. He does not expect to wind up his work in this area any time soon.

Today's technology "is irresistible," Mead said. "It is the most incredible intellectual endeavor of all time, and digital computers are just the first baby step. I'm much more excited than I have ever been."

—Tekla S. Perry

MASARU IBUKA: farsighted founder

"I invent because making new things provides one of the biggest joys of my life—a satisfaction of my curiosity," Masaru Ibuka told *IEEE Spectrum*. "Sony was established as a result of this drive," added the company's honorary chairman and cofounder.

Ibuka thinks deeply about a problem until he arrives at, in his words, "a vision that illuminates its overall nature." To that approach he surely owed his speed in recognizing the significance of the transistor. His success in capitalizing on the insight, though, is as surely also due to his refusal to be distracted by "negative opinions" or failures.

His creativity seems unquenchable. Since founding Sony Corp. in 1946 with Akio Morita on US $500, Masaru Ibuka has invented and promoted a whole string of consumer electronics firsts: Japan's first all-transistor radio, a transistorized television, a videocassette recorder for home use, the Walkman personal stereo, and a compact-disc player, among others. Now 83 and retired from corporate life, he still exercises his innovative energies in research into early childhood education and non-Western medicine.

Ibuka was born in 1908 in Nikko City, Tochigi prefecture, north of Tokyo. His father, an engineer, died when Ibuka was three. His mother, a graduate of Nihon Joshi Daigaku (Japan Women's College), taught for many years at the kindergarten associated with her alma mater.

Radio enthralled Ibuka, even as a boy. Dissatisfied with the simple galena-crystal receivers that most amateurs used, and eager to listen to 250-W test broadcasts from distant Osaka, he built a three–vacuum-tube set—but because vacuum tubes were scarce and expensive, the resourceful 17-year-old fabricated his own.

He patented the first of his many inventions when he was still an engineering student at Waseda University: a "running neon" light in which a high-frequency current modulated the luminous gas in the tube so that it seemed to undulate. Around the same time, he used a Kerr cell to modulate light in early Japanese "talkies." Today he has 104 patents to his credit.

Then in 1953, he secured from AT&T's Western Electric Co. a license to manufacture the transistor in Japan. This paved the way for what he views as his most gratifying innovations: the transistorization of radios, televisions, tape recorders, and videotape recorders. "I recall the satisfaction I felt in initiating, coordinating, and managing each of these projects," he told *IEEE Spectrum*. Also high on his list is his development of the Trinitron color television receiver and the Jumbotron large-screen television display.

Ibuka's most fruitful periods coincided with two of these developments. "The first was the time we mass-produced a transistor radio in 1955—something that everyone said was impossible," he said. The second was 1961–68, when he was developing the Trinitron and its production system.

He remembers well his struggle with transistorization and his single-mindedness. "I paid no heed to negative opinions," he said.

Sony Corp.

Masaru Ibuka talks to a visitor to his Early Development Association.

"I just went about my work in earnest. Everyone told me it was too early to attempt manufacturing a transistor radio, but I went ahead anyway. I also started work on developing silicon for use in consumer products such as TV receivers, though that kind of research was not even being conducted in the United States."

The environment he works in means little to Ibuka, but he does prefer to be physically near the team overseeing a project. He communicates his vision of a problem to his staff, and he and they work together, exploring alternatives, before they decide on the direction to take to a solution. As the work progresses, he frequently reorganizes project teams.

If he finds that the direction he has chosen is approaching a dead end, he simply changes to an alternative direction. This shifting he can do easily, he finds, because his target is so clear. "I have had countless failures in my career," he said, "but I don't let that bother me. I just forget about the failure and try again. I have never suffered from burnout."

—George F. Watson

JOHN R. PIERCE: writing to clarify

Always a tinkerer, John Pierce built machines with a kind of erector set as a child. In high school, he constructed a glider (that never did get off the ground). And during his decades at AT&T Bell Laboratories, Murray Hill, N.J., he generated a steady stream of innovations that affected the future of photomultipliers, traveling-wave tubes, and time-division switching.

But Pierce's best inspiration came not from tinkering, but from writing. As a scientist with a strong interest in science fiction—Pierce has published some 20 short stories under the pseudonym J.J. Coupling—he was occasionally invited by various groups to give talks on space, showing pictures taken from V2 rockets and hypothesizing about the future of human space flight.

In 1954 the Princeton, N.J., Section of the Institute of Radio Engineers (one of the IEEE's predecessor organizations) asked Pierce to speak at an upcoming meeting. But, on sitting down to write his speech, Pierce thought, "I can't give them all this man-in-space guff."

What he came up with instead was an idea for orbital radio relays, or communications satellites. "It seemed an obvious idea," he told *IEEE Spectrum*. "You put a satellite up in space to communicate by microwaves to some distant place." After thoroughly analyzing this possibility, he was surprised to find out just how simple it would be to implement. A satellite would not need much power; in fact, it could be passive and merely echo the signals sent. (Pierce was unaware that science fiction writer Arthur C. Clarke had several years earlier conceived of a manned space station that would perform communications satellite functions.)

After his talk, Pierce found himself more excited about his subject than his audience was. He set about persuading his managers at Bell Laboratories to pursue launching a communications satellite. At first he met with some skepticism, but then Sputnik was launched, making Pierce feel like "a writer of murder stories who comes home and finds a body in his living room—suddenly, it's for real." With a change of management at Bell Labs, including managers enthused about communications satellites, the project went ahead, resulting in Echo, launched in 1960, and Telstar, in 1962.

Pierce's other breakthroughs came about in less dramatic ways. At the California Institute of Technology in Pasadena—which he entered intending to pursue a career in chemical engineering until he discovered he was inept at freshman chemistry—Pierce researched sampling oscillographs for his Ph.D. thesis. This work came in handy during his early days at Bell Labs, when he collaborated with William Shockley on designing photomultipliers. The pair solved the difficult problem of designing electron flow by building a thin rubber trampoline measuring 1 by 1.2 meters, with wooden support blocks representing electrodes. Rolling ball bearings on the rubber, they would direct them by adjusting the wooden blocks. With this model, they could predict the paths of electrons.

Though the designs for the photomultipliers were a success, they did not become a product for AT&T. Intended for use in movie sound tracks, the devices were shelved when the company left that business. Today, photomultipliers are used in low-level-radiation–sensing applications ranging from astronomy to computerized tomography.

Continuing his work on electron flow after the photomultiplier project ended, Pierce developed a way to converge electron flow with his Pierce Gun, a device that generates electron beams, which became a key component in traveling-wave tubes and in klystrons.

Later Pierce designed what he called the double-stream amplifier, one that used two electron streams and no circuits for amplification. "It wasn't good for anything," he said, "but it was a wonderful idea."

For about 10 years, from the mid-1940s until his passion switched to satellite communications in the mid-'50s, Pierce worked on traveling-wave tubes that are still used in communications satellites. This work was done in parallel with British scientist Rudolph Kompfner. Pierce's greatest contribution to the technology was to create a high-loss, instead of a low-loss, circuit, to solve the problem of

instability faced by all traveling-wave tube designs at that time.

In the early 1960s Pierce moved up the Bell Labs hierarchy, becoming less involved in direct research. He still contributed to advanced technology, though, pushing time-division (or digital) switching over space-division switching. He also tried to promote the concept of digital correspondence, better known now as electronic mail, but with the then-current technology, it was not practical and the idea languished.

This was a surprise to Pierce. "I would have predicted the success of electronic mail and the digital office long before that of communications satellites," Pierce told *Spectrum*. "Satellites seemed sort of crazy to me—that was space. Electronic mail was practical, down-to-earth. But the technology was ready for space and it wasn't ready for the digital office."

At Bell Labs, Pierce kept regular work hours, seldom taking work home, although, he said, his ideas about things he was working on always absorbed him. An only child who was held back a year in school because of difficulty socializing with other children, Pierce works best alone, but he did enjoy the camaraderie of Bell Labs, where experts in everything he needed to know were always anxious to talk about what they were doing. That hobnobbing prevented Pierce from ever becoming expert at digging information out of published scientific literature.

He also kept in frequent touch with colleagues in Japan. (He received the first Japan prize in 1985, an award for technical contributions that the sponsoring Science and Technical Foundation hopes will some day equal the Nobel Prizes in prestige.)

Typically Pierce stays with a technology only until it is well enough developed and other researchers and mathematicians have begun work in the area; then he moves on. "I'm better at the early stages of things," he said. "I'm a low-grade theorist. Or maybe it's that I have a short attention span."

When beginning a new research thrust, Pierce attempts a mathematical analysis. "First I usually can't remember that part of mathematics that I need, so I flub around. Then I get hold of it by the wrong handle, so that instead of things getting simpler, they get more and more complicated. But as I struggle with it, sometimes I'm fortunate enough to see the light, and finally I get an answer."

The answer may come while he is in bed, waiting for sleep, or else while traveling. But insights arrive only for problems he has already been worrying about. He never has unconnected flashes of inspiration, he told us.

Part of the process of innovation for Pierce is writing. "Writing technical papers is explaining things to myself," he said, "I'm never sure I understand something until I set it down coherently."

In 1971, after 35 years at Bell Laboratories, 61-year-old Pierce had, it seemed, run out of ideas. "I didn't know what I wanted to do next," he said. And mandatory retirement at age 65 was looming.

"I don't know how to do anything except work," Pierce told *Spectrum*. And he likes seeing things exist that would not have been around if he not created them. So he began battling against burnout and retirement.

Deciding it was time for a change of scene, he left Bell Labs and went back to his alma mater, Cal Tech, as a professor of engineering. There he taught a course in communications, directed several graduate students, and faced the tribulations of raising money for research. Being in academia was not an entirely natural role for him, he recalls, but nevertheless he remembers the time as an interesting experience.

Then in 1979 he received the Marconi International Fellowship, a grant of US $25 000, which he decided to invest in writing a book. *The Science of Musical Sound* (Scientific American Books, New York, 1983) evolved from an interest he picked up at Bell Labs from one of his researchers who wrote computer software to generate musical sounds.

He retired from Cal Tech in 1980 to become chief technologist at the Jet Propulsion Laboratory in Pasadena, where, he said, "I can't say I contributed a great deal, but I came to admire [that laboratory] tremendously." Retiring from that job in 1982, he joined California's Stanford University faculty as a visiting professor of music emeritus, where he continues to investigate sound at Stanford's Center for Computer Research in Music and Acoustics.

Today, Pierce, 81, is pursuing yet another idea that intrigues him. A few months ago, listening to a gong being struck by a soft mallet, he discovered that, whereas most instruments generate sounds whose high frequencies decay first, a gong's high frequencies increase after it is struck. He began analyzing the problem, discovered that there is a nonlinearity that transfers energy to higher frequencies, and has written a paper on the subject. Recently he also discovered how to re-create the phenomenon with vibrating strings.

"It was a new phenomenon, upsetting somehow," Pierce told *Spectrum*. "I understand more about it now than when I first heard it," but not enough, yet, to know where this latest exploration will take him.

—Tekla S. Perry

Jon Brenneis

John Pierce conducts an acoustical experiment on a vibrating-string instrument.

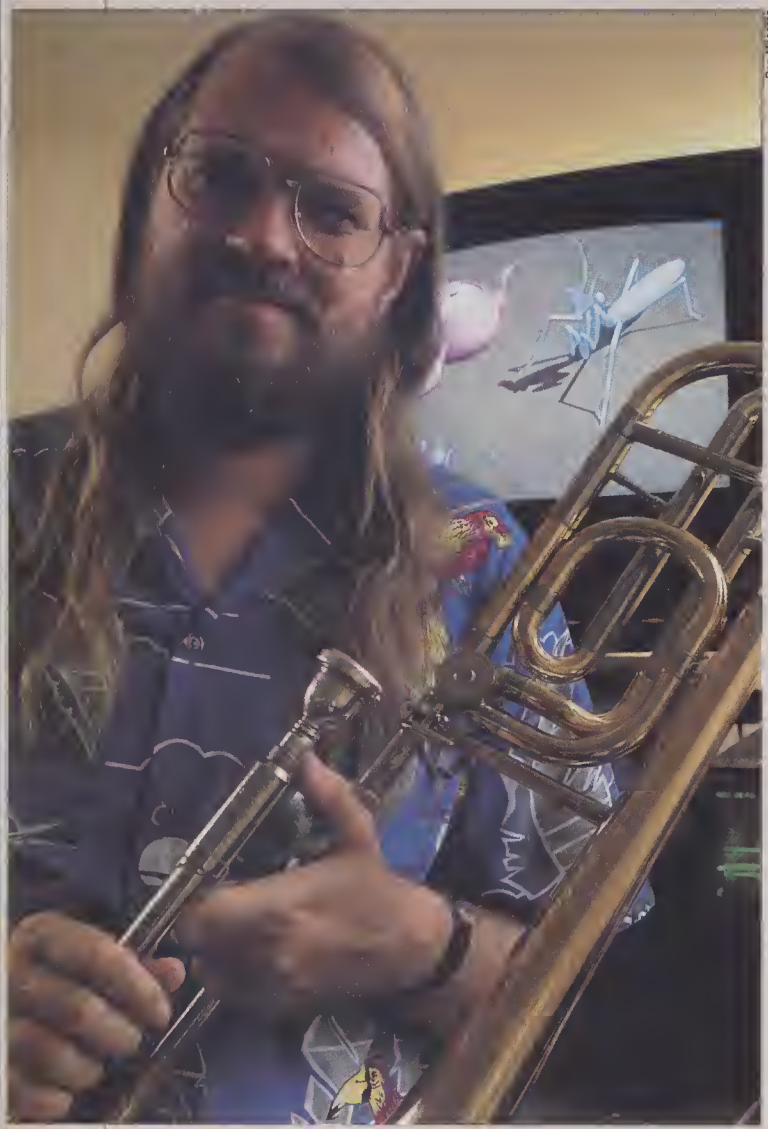
JAMES F. BLINN:
artist-mathematician

"I want to have something with my name attached to it," James F. Blinn told *IEEE Spectrum*. "Everybody remembers the tool user but nobody remembers the tool builder. Nobody knows who invented oil paints, but everybody knows who Picasso is."

As associate director of Project Mathematics at the California Institute of Technology in Pasadena, Blinn is currently working as a tool user: doing graphic design for computer animation. This job enables him to work simultaneously as an artist, educator, mathematician, and scientist.

Among his successes has been the creation of animation for a simulation of the Voyager spacecraft's flyby of Jupiter and Saturn that was widely shown on television. He has also done a video simulation of DNA replication, originated computer animation for Carl Sagan's "Cosmos" television series, and designed a 7½-hour-long animation sequence for "The Mechanical Universe," a video series for college physics students. He is now working on a similar video for high-school mathematics students.

Blinn's earlier work—up to about 10 years ago—was in tool building: inventing techniques for image synthesis. To put textures on surfaces, he developed bump mapping. To make surfaces look shiny and metallic, he created reflection mapping. These were just two of the many methods he developed to simulate how light interacts with surfaces.



Ron Mesarós

Jim Blinn prepares for a Caltech Wind Ensemble concert.

When he tackles a design problem, Blinn first examines details, then backs up to look at the totality, and then examines the details again—going back and forth in an iterative process. By solving some concrete details first, he gets a feeling of making progress.

Flashes of insight and inspiration come at unexpected moments, he finds. He recalled one day looking at the fine-grained patterns on his leather shoes, then suddenly conceiving an efficient way of replicating them on a video screen. He would start with a perfectly smooth surface and, to simulate light interaction, slightly perturb the surface to make it look as if it had wrinkles.

Early frustration with real-world constraints may have influenced Blinn's career. As a boy, he was inspired by articles in *Popular Electronics* to carry out several electronics projects. But living in a small town, he had to order parts by mail. "Six weeks or six months later, half would come," he said. "They'd be back-ordered and I never got everything all together. I was always frustrated with doing things in the real world with physical components."

When he started college, "getting into computers was the ideal thing," he said. "You never run out of ADD instructions. It was the right balance between theory and practice."

By the time Blinn was 25 and in graduate school at the University of Utah in Salt Lake City, he was breaking altogether new ground in computer graphics techniques.

The 42-year-old feels his most prolific period so far was between the ages of 35 and 38, when he was involved in "The Mechanical Universe" project. There was much to be done, and he had committed himself to a schedule. His work on the video series also pleases him most. He was happiest when doing the section on relativity. "In college, relativity didn't make sense to me," he told *Spectrum*, "until I found a book, *Relativity in Pictures*, that had a series of cartoons that made sense. Fifteen years later, I was able to do animations of them to help relativity make sense to other people."

Indeed, the desire to explain math and science to others is a major motivator for Blinn. "I want to share my enthusiasm," he said. "I think math and science are fun. I want to tell people how interesting relativity is, how interesting the Pythagorean theorem is."

Blinn does his work in the former master bedroom of a small house at the edge of the Caltech campus. He finds it a pleasant environment—perhaps too pleasant; he worries that he is not accomplishing as much as when he worked in a spartan, warehouse-like environment at the Jet Propulsion Laboratory in Pasadena. "It seems you need some degree of discomfort in order to get work done," he said.

He usually rises at 11 a.m. and goes to the laboratory to interact with people—making phone calls and talking over current projects with co-workers. He goes out for dinner, then returns at night to do his "real work," for which he needs two things: solitude and silence. The work continues until he feels tired enough to go home.

While working, he snacks. "Mostly caffeine and sugar, pretzels, peanuts, corn chips, and lots of Coca-Cola," said the tall, slim Blinn, who is concerned that such treats could affect his productivity. "Maybe that's why I'm not getting as much done as I ought to. What you eat affects your digestion, which affects how much blood is left in your brain, I suppose."

Outside the laboratory, Blinn's big interest is music. He plays the trombone in the Caltech Wind Ensemble, a group of about 50 that gives several public performances every year.

Applause also accompanies his work. He welcomes it because it helps him obtain funding to produce educational video. "I make films that I would like to have seen when I was a kid," he said.

As for his own mentors, no one person was a major influence in his career, although he learned from many people, including his mother and stepfather, who were art teachers. Mostly, though, he learned by reading books and "tinkering" on his own.

—George F. Watson

S. Chiba

Jun-ichi Nishizawa's static induction transistors power the sound system in his study.

JUN-ICHI NISHIZAWA: maverick in Japan

Academic circles in Japan reacted with dismay when Jun-ichi Nishizawa proposed radical new semiconductor devices. Though the inventions included the semiconductor injection laser, almost no one in Japan recognized their potential at the time, and Nishizawa, a professor at Tohoku University, spent many frustrating years trying, with limited resources, to demonstrate their value.

Among those other inventions were the p-i-n diode, ion implantation, p-i-n photodiode, n-p-i-n transistor, avalanche photodiode, and static induction transistor—all around 1950—and the n-p-i-n drift transistor in 1954. After he applied for patents for semiconductor lasers (outside-resonating in 1957, internally resonating in 1960), his interests expanded to optical fibers for communication, and in 1964, he invented the graded-index optical fiber.

But it was not until 1968 that he at last persuaded university officials to set up the Semiconductor Research Institute, a quasi-independent, off-campus laboratory. This was—and still is—an unusual arrangement in Japan, but it has paid off. With Nishizawa at its helm, the research institute has developed many technologies from the university and transferred them to industry.

The holder of 700 patents that have won for him international recognition and numerous awards, Nishizawa is proudest of his ideas for optoelectronic devices and optical communications but regrets he could not develop them further himself for lack of support. However, he was able to develop as well as invent the vapor-pressure control technique for growing high-quality crystals of stoichiometric gallium arsenide. With his advice, Sumitomo Electric Co. and Mitsubishi Materials Co. have made 10-cm-diameter GaAs wafers—the largest yet with acceptably low defect density.

In power devices, too, he has had the satisfaction of developing his ideas for practical applications. Under his direction, the static induction transistor's (SIT's) potential as a fast, efficient power control device is being realized. SITs are being used as output transistors in 500-kW commercial radio stations in Hiroshima, Sendai, Osaka, and, soon, Tokyo, while Toyota Corp. is using SITs in forklift trucks.

Nishizawa expects another of his inventions, the silicon induction thyristor, to be used as an ac-dc converter for high-voltage dc (HVDC) power transmission. The device's 99 percent conversion efficiency may allow for 10 000-km HVDC routes and make hydroelectric power accessible throughout the world, eliminating the need for new fossil-fuel and nuclear plants.

A desire to "improve the living conditions of every human being" motivates Nishizawa, he told *IEEE Spectrum*. At the start of his career, he primarily had the interests of his own country at heart, however. "We Japanese do not have many natural resources, even food, so we should invent and develop new technologies," he said.

His approach to work is to first examine the general nature and dimensions of a problem, then to concentrate on its details one by one—both by reading and by experimenting intensely till, with luck, a flash of insight leads to a totally new device.

Nothing illustrates this better than his invention of the p-i-n diode. In 1949 Nishizawa was struggling to understand the transistor. He started with semiconductor diodes, however, because they were more fundamental. For a year, he tried in vain to reproduce the phenomena reported by Nevil F. Mott in England and Walter Schottky in Germany. So he struck out on his own, hoping perhaps to improve diode rectification in the process.

"I spent mornings in the library reading recent papers and afternoons in the laboratory experimenting," he recalled. "Evenings I spent analyzing the results, thinking, and reading fundamental books." In so doing, he found a paper by W.P. Jousé that suggested inserting an insulating layer between a diode's metal and semiconductor layers. Nishizawa built this structure and found that it did indeed rectify. On reflection, he determined why: it was based on accelerated carriers in a semiconductor. "Today the principle is called 'hot electron' theory," he said. "The carriers are able to jump into the insulating film and make it conductive."

Nishizawa did not stop there. He continued thinking and experimenting until he found the ideal material for the insulating film. That proved to be the semiconductor material itself—a layer with

few impurities, that is, an intrinsic layer. If an intrinsic layer were sandwiched between layers of p-type and n-type material, it would yield a p-i-n diode, which would be fairly easy to build, resist higher voltages, and have higher efficiency than a pn diode did.

But farther than that, Nishizawa could not go. He pleaded with university officials and industry managers for help in building an operational p-i-n diode, if only on a laboratory scale. He failed, and to his chagrin heard that Robert Hall of General Electric Co. in Schenectady, N.Y., had demonstrated a p-i-n diode several weeks after Nishizawa's patent application. Undeterred, he switched to other projects and has not stopped since.

Born in 1926, he is the second of five children. He remembers being a "mischievous" boy who made strange, inept ships and aircraft from wood. As a college major, fundamental physics or mathematics appealed to him, but because of his poor test scores in those subjects, his father discouraged him. Instead, Nishizawa told *Spectrum*, he studied electrical engineering at Tohoku. While in high school, he joined the chemistry club, despite disliking the field for "the large amount of knowledge" it required. But he reasoned that it could lead to future work in physics—as indeed it did.

Nishizawa's family has strong ties to Tohoku University. His father, now 99, was dean of the Faculty of Technology from 1945 to 1951. (His mother died in 1949.) A younger brother is a professor of metallurgy at Tohoku.

His most productive years? Nishizawa believes these were at ages 23 to 28, when his mind was fresh; 30 to 35, because he had improved his base of scientific knowledge; and 40 to 45, because of insights acquired into engineering.

While working, he demands quiet and solitude. Evening, he finds, is the time he is most effective, so he does not eat dinner until 11 p.m. "I like to be hungry when I am working to keep my head clear," he said. "Before noon I am a heavy coffee drinker. When I was younger than 45, I drank coffee even at midnight. But no alcohol." Ideas usually announce themselves when he is working around the house on a Sunday, cutting cord wood, for example.

For the future, said Nishizawa, "I still have many things to solve. My life is too short." For society, he is eager to find ways of obtaining energy without increasing carbon dioxide emission. His static induction thyristor may well advance this cause.

—George F. Watson

CHARLES H. TOWNES: masers, lasers, and more

In just 15 minutes in the spring of 1951, Charles Townes created the basic design for the maser. He scribbled his calculations on a scrap of paper, and put the scrap in his pocket, all the while sitting on a park bench in Washington, D.C., admiring a garden of azaleas. (He was slower inventing the laser, whose gestation lasted nine months.)

Townes was sure his maser design would work—he had spent five years struggling with ideas for producing extremely short radio waves for spectroscopic use. But outstanding scientists initially insisted his theory was wrong, he said, including Niels Bohr and John von Neumann. A few colleagues misinterpreted the application of the uncertainty principle; others simply doubted the scheme's technical feasibility.

Such opposition might have stalled a less confident researcher, but Townes said, "I didn't find it upsetting at all." "I don't mind people telling me that I'm wrong," he remarked on another occasion. "I have to try to examine for myself what is right."

The implementation of the maser would not be easy, he did grant that. It was fall before he, as a professor at Columbia University, New York City, finally found a graduate student he thought could handle it and was interested in the gamble—James Gordon. Later a bright young postdoctoral fellow, Herbert Zeiger, joined the project. Even then, after 2½ years of work, he recalled, the past and present physics department chairmen came to his office and said, in effect, "Look, you know this isn't going to work, both of us know it's not going to work, you're wasting money and should stop."

Townes disagreed, and the two left him alone (the job took three more months). The maser quickly found uses as a very precise oscillator and clock and also as an amplifier of microwaves more sensitive than any previously known.

"Disagreement is often important in the scientific process and calls for self-examination," Townes told *IEEE Spectrum*, "but it doesn't usually disturb me, although in a few cases I remember it being a nuisance."

He credits his parents with his capacity for being comfortable with unpopular views. They had a strong religious orientation, he said, and were quite ready to adopt a different position from the rest of society. "They didn't speak out against people who disagreed with them, but simply tried to consider what was right or wrong, and it was very clear that they expected us to be different when necessary," he told us.

Townes's work on the maser led to the laser—after a sabbatical in Europe and Japan and a few years researching the ammonia beam and solid-state masers. With masers operating in the 1–2-cm wavelength region, Townes wanted a device that would generate still shorter waves.

For some time in the mid-1950s, he waited for inspiration, but when it did not strike again, he decided to sweat out a reasonable way to reach his goal. After wrestling with the pertinent equations, he realized that it would be practical to abandon the pursuit of incrementally shorter wavelengths in favor of much shorter wavelengths—even the visible light range—where much more was already known.

About nine months' work with his brother-in-law, Arthur Schawlow, a Bell Laboratories researcher, completed the theory and design for the laser. Townes then started lab work with a student, but bowed out upon being appointed director of research for the Institute for Defense Analyses in Washington, D.C., a position he felt conscience-bound to accept. Townes received a 1964 Nobel Prize for his efforts and Schawlow a 1981 Nobel for closely associated work.

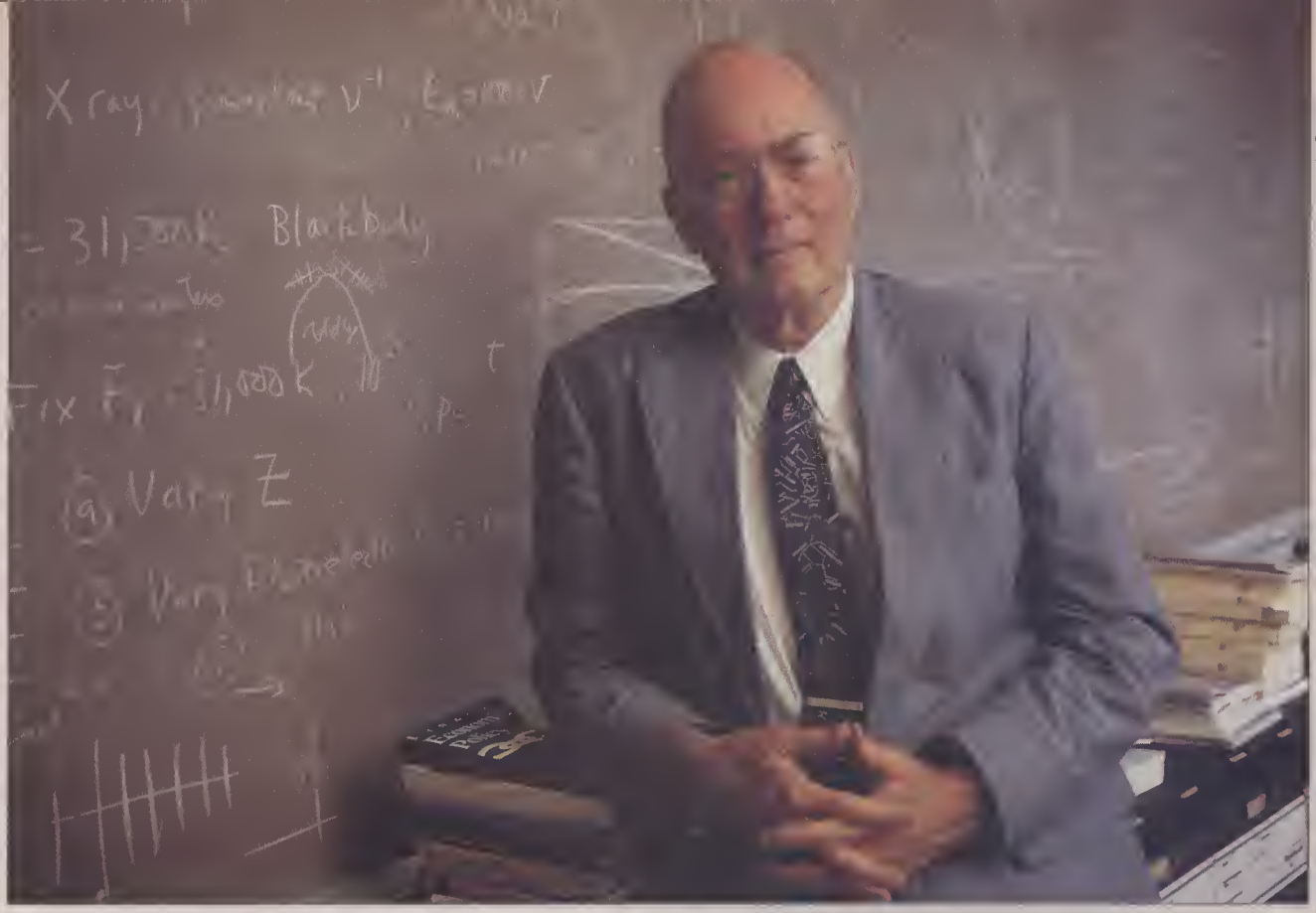
The maser and laser were by no means the sole focus of Townes's career. In fact, he has been loath to stay in any specialty for long. "Once a field is well established, I don't feel the need to do it any more," he told *Spectrum*. "It's just not as interesting to me to run with a crowd. It's more useful and much more fun to open up a new field."

This was a trait of his from childhood on. His earliest scientific interest was natural history. As children in Greenville, S.C., he and his older brother would catch insects and animals and collect leaves and rocks, classifying and displaying them carefully. But while he thought about studying biology in college, his brother "was so good at it I decided I shouldn't try to compete."

Anyway, as a 16-year-old freshman at Furman University in Greenville, S.C., he discovered mathematics and, next year, physics. Though he made the latter his specialty, because it had more to do with the real world than mathematics, physics was not a standard major at Furman, and by his last year Townes was teaching himself from a textbook. As a graduate student, he became involved in nuclear physics at Duke University, Durham, N.C., in 1936 and then at the California Institute of Technology in Pasadena until 1939. For his graduate thesis, he measured the spins of atomic nuclei. He had hoped for a postdoctoral fellowship at a top university, but Bell Laboratories made him his only offer.

Accepting, for a year he dipped into basic research areas before being assigned to radar navigation and bombing system design for the war effort. It was this work that suggested to him that microwaves could be used for high-resolution spectroscopy—a wholly novel idea that he began exploring in 1946, publishing papers and receiving several patents on the use of molecules for electronics.

His move from Bell Labs to Columbia University in 1948 did not affect his research. "I finally closed the book on microwave spectroscopy in 1955 by writing a book on it," Townes punned to us. "We had explored most of the physics, the field had developed, and



Jon Brenneis

Charles Townes talks about his current interest, infrared spatial interferometry.

it was time for me to move on and do something else."

The something else was masers and lasers, interrupted by the two-year stint in Washington. Next Townes moved on to the Massachusetts Institute of Technology (MIT) in Cambridge. He did some research, but as provost was mainly an administrator.

Meanwhile, lasers had become a hot subject, one he felt no longer needed him, though he was impressed by the rate of their development. "I knew from the beginning that it was going to be important, because it married the fields of optics and electronics," he said, "though some people kidded me that the laser was an idea looking for an application."

In short, it was time for another change—to radio and infrared astronomy. At several other points Townes had eyed the field, but more pressing interests had intervened. "I felt that astronomers were missing good bets by neglecting to look for stable molecules in interstellar regions and in not fully using new technologies to work in the infrared and microwave regions," he told *Spectrum*.

He had in fact predicted the molecules' existence in a 1955 paper written during his sabbatical. But apart from his brief studies then, he knew little about astronomy. So, stepping down as an administrator at MIT, he spent a year studying the subject, largely at neighboring Harvard. Then in 1967 he moved to the University of California at Berkeley, to teach physics and begin what became an extensive program of experimental research in astronomy.

One of his first efforts was to look for those stable molecules in space. With other colleagues at Berkeley he found ammonia and then water, which, to his surprise and delight, was producing powerful natural masers in space. This work demonstrated for the first time the presence of dense molecular clouds—another field Townes left when it rapidly turned popular.

He turned to mid- and far-infrared spectroscopy, particularly of the galactic center. There measurements by Townes and colleagues have shown the presence of a very massive object, presumably a black hole. Most recently, he has switched to infrared spatial interferometry with the goal of obtaining angular resolution on astronomical objects one or two orders of magnitude higher than has been previously possible at infrared wavelengths. "It is a tough thing to do, but I think quite important," Townes said. "In the long run it could open up a very exciting field."

All these changes of direction have kept Townes fresh despite long hours. (He works many nights and most Saturdays.) He finds it stimulating, too, to exchange ideas with other researchers. He developed the maser, for example, he said, in a laboratory where others were working on molecular beams. Also, several weeks before his sudden insight, he had heard a German researcher give a talk on high-intensity molecular beams, and he had recently read a seemingly unrelated paper on negative temperatures.

He has held burnout at bay, Townes believes, with a rule he has kept throughout his career: he does not even think about physics on Sundays. "Whenever I start, I tell myself, 'wait a minute, worry about that tomorrow,' " Townes said. "Taking a complete break like that keeps me refreshed." During those hours, he dabbles in a variety of hobbies, from hiking to scuba diving, none of which, he said, he takes seriously.

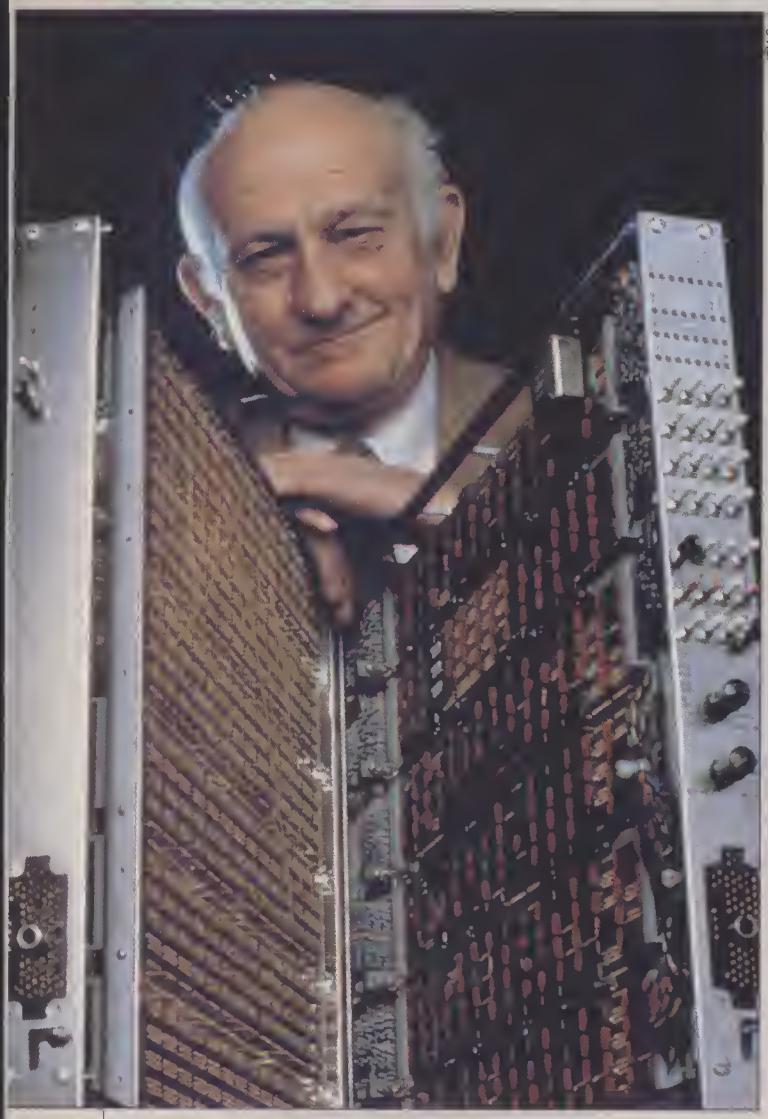
"Physics," admits the 76-year-old scientist, "is my only permanent hobby."

—Tekla S. Perry

JOHN COCKE: vision with enthusiasm

Burnout has never bothered John Cocke, the inventor of reduced-instruction-set computer (RISC) technology. His interest in all parts of the computer business and his ability to "always find something a little different" to engage his attention have led to some 22 patents. Besides those for RISC technology, his patents cover logic simulation, coding theory, and compiler optimization.

Inventing is something Cocke does with great enthusiasm. A self-motivator, he does not feel acceptance or acclaim are important for motivation. In fact, he enjoys discovering his mistakes because "that is when you learn something." But he recalls no major failures in



John Cocke with the 801 minicomputer system, a RISC research prototype completed in 1980.

his career.

Cocke's approach to solving problems is not guided by rules or any particular philosophy. He feels that solutions come through continuous work and does not remember ever having had dramatic flashes of inspiration. Claiming that he is clumsy at using a keyboard or a mouse, he prefers a pencil and paper or a blackboard. He also told *IEEE Spectrum* that he is more diagram- than word-oriented.

His most productive period, Cocke feels, was when he was about 35 and "wildly interested in computers." At that time, he had the opportunity to work in the laboratories of IBM Corp. with such luminaries as Frederick P. Brooks Jr., now Kenan Professor of Computer Science at the University of North Carolina, Chapel Hill. Cocke describes those days of freedom in thinking, when there were few known procedures at IBM, as energizing, but, ever self-effacing, said he was "just there to learn."

Cocke's keen intellect is combined with an avid curiosity and an ability to totally immerse himself in a technical challenge, according to colleagues. "The smartest man I ever met," said Joel S. Birnbaum, vice president and general manager of the information architecture group at Hewlett-Packard Co., who was once interviewed for a job by Cocke at IBM and subsequently worked there. Lewis M. Branscomb, director of science technology and public policy at Harvard University, Cambridge, Mass., and a former IBM chief scientist, describes Cocke as "one of the very few people I know whose IQ is higher than his blood cholesterol level."

Cocke's interest in inventing was sparked at an early age by an uncle's comment that you could catch a bird by putting salt on its tail. But his attempts to develop an effective salt sprayer failed. He also experimented early on with a device to wash windows. This invention worked. By moving an electromagnet on the inside of a window, he was able to cause a piece of iron attached to a cloth to move in tandem on the outside. Another of his first experiences with "inventing" was a hydraulic pipe wrench. Its jaws were opened and closed by pressing a button each time. But he discovered that such a wrench had already been patented in 1890.

Born May 25, 1925, in Charlotte, N.C., Cocke was the youngest of three sons. His father was chairman of the board of a local power company. Because Cocke was not a good student in grammar school, his mother had to have him tutored. When he got to high school, he did a little better by studying general science and physics, courses he took to avoid taking Latin, a subject he considered "too difficult." The mathematics he felt he could handle without a lot of study, he told *Spectrum*.

He fared even better at Duke University, Durham, N.C., where he received a bachelor's degree in mechanical engineering in 1946. His courses in engineering and physics were selected because "they were easier" than art courses, which he felt would have been "too difficult memorizing hundreds of paintings and painters."

As a student at Duke, he had been in the U.S. Navy's V-12 program and was called back into the Navy in 1952. In the interval from 1946 to 1952, he held several jobs, including one with a heating and air-conditioning company and another with General Electric Co.'s high-voltage laboratories.

Cocke returned to Duke in 1954. While there, he took a summer job at Patrick Air Force Base in Florida, where he designed a Monte Carlo program to determine the optimum number of aircraft required for delivering supplies to the Bahamas. After receiving a doctorate in mathematics from Duke, he joined IBM in 1956. The decision to go with IBM at that time, he said, was a lucky one: it put him where the action was in computer development.

Over the years his work habits have changed. When he was younger, he arrived at work late and stayed late, principally to have access to a computer, a scarce resource in those days. He often stayed up all night, he said, so satisfying was it to get a lot done. Now, because he needs "to sleep at night," his work hours are more routine.

In his younger years, too, Cocke used to ski, play golf, and unicycle. He has never been a game-playing type, he told us. He prefers, for example, to speculate on how to build a chess-playing machine, rather than to play chess itself.

Cocke's successes have been recognized at the highest levels. In September President Bush named him a recipient of the 1991 National Medal of Technology "for his development and implementation of Reduced Instruction Set Computer (RISC) architecture that significantly increased the speed and efficiency of computers, thereby enhancing U.S. technological competitiveness."

In 1987 Cocke received the Turing Award from the Association for Computing Machinery—the group's highest honor—for technical contributions in computing. In 1990 he was the first to receive the US $100 000 IBM John E. Bertram Award for sustained technical excellence. In making the award, IBM chairman John F. Akers said, "John has that rare ability to understand and synthesize both hardware and software concepts, optimize the design of both, and produce a unique synergy."

Last year a group of Cocke's colleagues held an all-day symposium celebrating his 35th year with IBM. Some attendees also participated in a videotape, "John Cocke: a retrospective by friends." On the tape, Abraham Peled, now IBM's Research Division vice president and director of computer sciences, remembered being interviewed by Cocke. "John asked what my thesis topic was," he said. "After I had talked for about 5 minutes on the topic—digital signal processing—he went to the blackboard and more or less wrote out a major part of my thesis. It was a rude awakening."

In reflecting on his career, Cocke is self-critical. "Things have always taken too long," he told us. —*Ronald K. Jurgen*

(Continued from p. 24)
is when you learn something." But to admit one is wrong or does not know is not easy, especially in expert high-technology cultures where status depends on never having to say, "I don't understand." Arno Penzias, vice president of research for AT&T Bell Laboratories, once told me that one of the major drags on innovation at the labs was the reluctance to admit ignorance.

Any analysis of the psychology of innovators must focus not only on cognitive style, but also on character. The innovator is confident he can solve a problem if he sticks to it. Thomas Edison is said to have stated that genius is 1 percent inspiration and 99 percent perspiration. What this leaves out is the courage to innovate, to invest one's time in an idea and affirm it against resistance. It is not necessarily the case that if one invents a better mousetrap, the world will beat a path to your door. Even IBM Corp. took 10 years to adopt the reduced-instruction-set computer (RISC).

Not only are new ideas doubted, but also they threaten those who profit from older ideas. Carver Mead spoke about "the huge amount of negativism" he has experienced. "Looking back," he said, "it was clear that in that case the reason there was negativism was that people did not want systems designers designing silicon, because it was an entrenched industry with a vested interest. . . . I had known the early semiconductor industries. They were the most innovative places that I had ever been. What I had not realized was that they had aged and had gotten entrenched, and they had a vested interest now. Whereas when I knew them, they were trying to break in, now they were entrenched and they didn't want anyone breaking in on them."

Mead recognizes that there are winners and losers in the market. To realize his innovations, he must participate in the world of business, facilitate the market forces that ultimately determine the winners.

What motivates the innovators? Recognition is enjoyed, but it is not the main drive. As Ibuka summed it up, "I invent because making new things provides one of the biggest joys of my life . . . ." Pierce said, "I do like to see things that wouldn't be there without me." As we see from the interviews, the drive to innovate is complex. It includes curiosity, challenge, and a spirit of disciplined play. Innovation gains meaning in its significance to human progress. But I suspect that, even more, the innovators' satisfaction is in understanding and creating.

I believe the innovators provide clues for developing people who are more innovative. It seems to me a matter of three elements: cognitive style, character, and supportive environment. Innovators behave as they do out of a sense of freedom. Yet they can work harder, concentrate more intensely, than if they had been forced to work at a task set by someone else.

This sense of freedom is rooted in their independent spirit and courage. I have the sense that, in general, they were not disciples of mentors, but rather used good teachers. Their goal was not to become good students, but rather to become masters. However, this independence has been buttressed by a sense of security that perhaps was nurtured in childhood, but was certainly affirmed by supportive institutions. Having tenure at a university or its equivalent at Bell Labs, IBM, or Sony Corp. makes a big difference, particularly to an innovator who is not trying to please the powers that be and in fact may threaten them.

There are two ways to think about motivation. One is extrinsic motivation, which has to do with control, getting people to do something they may not want to do. The theories of psychologist B. F. Skinner describe how the use of rewards, or "positive reinforcement," increases the probability of occurrence of a behavior. What proponents of this theory leave out is that Skinner obtained his results by first starving his subjects, rats and pigeons, and doling out pellets of food when the "correct behavior" occurred.

Skinner's approach may generate compliance but not innovation. In the 1950s, another psychologist, Harry Harlow, showed another kind of motivation: that monkeys learned to solve problems that appear to be interesting challenges. When they were subsequently rewarded with bananas for solving a problem, such as opening the lock on a door, their performance deteriorated. At the least, Harlow was showing that fully fed and secure animals are intrinsically motivated to solve problems. There is no need for other incentives. Rewards may have confused them. Rather than pursuing the enjoyable task of problem-solving, where they were in control, they were thrust into working for bananas, over which they had no control. And so it is with human beings.

While these interviews suggest ways to strengthen the innovative spirit in organizations, the first question is: who wants more innovators? On the one hand, innovation drives progress and creates wealth. On the other, innovators threaten the status quo. I was once with the chief executive officer of a large company who was asked, "How many real innovators do you have in your company?" "I don't know," he answered. "But I'd like to know who they are, so that I can keep my eye on them." Innovators pursue projects that may or may not be useful to a company and may tie up resources that could be employed elsewhere.

In great corporations, innovation must be managed. The trick is to recognize and support the exceptional person who sets his own problems while providing the others with a framework for innovative problem-solving. Although not everyone has a systems mind, good management can teach people how to see the organization as a system with goals. Everyone can learn the logic of business strategy and the need for organization that supports this strategy. Everyone can be engaged in continuous improvement.

Some Japanese companies, with the help of quality control pioneer W. Edwards Deming and other gurus, have understood this better than most Americans. When I visited Toyota Corp. in Nagoya, I was shown long lists of ideas for improvement suggested by front-line workers. I asked how many ideas each worker offered on the average. The answer: 47, of which 80 percent were adopted. That seemed impossible, almost an idea a week from each worker. A Toyota manager responded. "I have visited your factories," he said, "and you have a different view from ours. You are pleased when there are no complaints from the workers, but for us, each complaint is a potential idea, and an opportunity for improvement."

The improvement of quality, according to Deming, is a combination of innovation and incremental improvements in product and process. These create new value by satisfying needs, generating new tools, lowering costs, and enhancing human life. The companies that succeed in the markets of the 1990s will be those best able to make use of innovation, and to continuously improve quality by balancing discipline and freedom, setting clear goals and high standards, and offering opportunities for innovation—work and play.

ABOUT THE AUTHOR. Michael Maccoby is a consultant on leadership, strategy, and organization to business, government, and unions. He is president of The Maccoby Group, Washington, D.C. He has a B.A. in social psychology and a Ph.D. in social relations from Harvard University, Cambridge, Mass.

TO PROBE FURTHER. Michael Maccoby has contributed to *IEEE Spectrum* before, most notably the article "'Winning' and 'losing' at work" [July 1973], which was the genesis of his bestseller *The Gamesman*. Most recently, he edited *Sweden at the Edge: Lessons for American and Swedish Managers* (University of Pennsylvania Press, Philadelphia, 1991).

Jacques Hadamard describes the similarity of creative processes in mathematics, science, and the arts in *The Psychology of Invention in the Mathematical Field* (Dover, New York, 1945). Dean Keith Simonton develops a theory of creativity in *Scientific Genius: A Psychology of Science* (Cambridge University Press, Cambridge, United Kingdom, 1988).

Early in 1992, the IEEE Life Member Fund will publish a compendium of reminiscences of almost 200 Life Members about their careers in engineering. The collection will cover their education, motivation, difficulties, and achievements. For further information, contact IEEE Field Services, 445 Hoes Lane, Piscataway, N.J. 08855-1331.

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IEEE's Posix: making progress

Seven more standards are near completion in this cornerstone of the international open-system software effort

As the circuit design deadline drew near, the pace became more frantic by the hour, elevating the project leader's anxiety level and his blood pressure. And for good reason—all the users of DEC workstations, where the computer-aided design software resided, were out at a seminar. To be sure, IBM, Sun, and other workstations were available that would have allowed other engineers to complete the job on time. But the software? Only a DEC version was obtainable in house; in no way could it be ported to the IBM or Sun on time to beat the deadline—even though the project leader had received assurances from the software vendor that such versions "were forthcoming."

This scenario is not as fictitious as it might seem. It reflects a growing concern among engineers as well as other users of software with the need for portability and interoperability of software. Portability refers to the ease with which a software system or component can be transferred from one hardware or software environment to another. Interoperability is the ability of two or more computer systems and their software to exchange information and use the information that has been exchanged.

Though the work needed to bring about industrywide portability and interoperability is extensive, there is hope. Efforts have been under way for some years in the form of the so-called open system standards. An important part of that effort is the interface standards within the IEEE portable operating system interface (Posix) environment. (The X in Posix denotes the Unix operating system origin of this effort.) At least one of these standards—No. 1003.1, which covers basic operating system services—was adopted last December as Standard ISO/IEC 9945-1 by the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC)—both in Geneva, Switzerland.

D. Richard Kuhn
National Institute of Standards and Technology

Today there are 19 Posix working groups involved in 26 projects. Likely to be completed within the next 12–18 months are standards for such tasks as handling command language and utilities (Standard 1003.2), real-time programming (1003.4), and controlling access to computer files (1003.6).

The Posix efforts have been supplemented by the IEEE Technical Committee on Operating Systems with other projects to develop standards for application interfaces to services [see table, p. 39].

Additional open system standards have been developed through the American National Standards Institute (ANSI), ISO, and other organizations. These focus mainly on such specialized aspects as programming languages, databases, and communication protocols. In contrast, Posix standards cover operating system services in general.

Many of these other specifications have been combined with the developing IEEE standards to define an open systems environment using the Posix interface standards as the basis. Already products abiding by the Posix standards have emerged from vendors, including such industry leaders as IBM, Digital Equipment, Sun Microsystems, Apple Computers, and AT&T's NCR.

In the offing: a major new industry geared to standard software components

Not only are the open system standards within the Posix activity expected to resolve the portability and interoperability problems, but they are also expected to open the door to a major new industry of standard software components, or modules. From these components, users will be able to build and modify larger systems to suit their evolving needs. Such components will eliminate the need to produce several versions of an application program to accommodate operating systems with different file system structures and network interfaces, making them more attractive to software developers.

Standard components for software have been advocated for at least two decades, but until recently only limited versions of such components—mathematical subroutine libraries, for example—have been available.

Barriers to more complex components have been both technical and economic. Though such modern programming languages as C++, Objective C (an object-oriented version of C), and Ada are helping to solve technical problems associated with component development, a software component created today in a language such as C++ must still use system services that vary. They must depend on the operating system, database, communication interface, and other vendor-specific functions. If a component makes extensive use of VMS system services, for example, then a different version of the component must be created for Unix System V. (VMS is a popular operating system for Digital Equipment Corp.'s computers.)

INTERFACE SPEC. Evolving industrywide through a consensus process, open system standards will eventually change this situation. Generally, an open system standard is an interface specification to which any vendor can build hardware and software products. Posix and related standards, however, refer only to software interfaces. If a vendor of a proprietary operating system software abides by an open system standard, it will provide software with the standard interface. This can be used to build portable software.

There are two kinds of portability—binary and source-code. Specifications for binary portability are designed for object code—a fully compiled or assembled program that is ready to be loaded into the computer. With binary portability, an executable copy of a program can be moved from one machine to another. In contrast, with source-code portability, a program must be recompiled first.

An example of a *de facto* standard for binary portability is the IBM PC machine-language instruction set. Executable copies of software can run on PC clones from many different manufacturers.

Of the two portabilities, binary portability is the more difficult to achieve because it puts constraints on the machine architecture and instruction set. Standards efforts,

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therefore, have concentrated on developing interfaces for source code.

Open system standards for source code portability define interfaces available to application programs for essential services like process control, file and directory access, interprocess communication, and graphics.

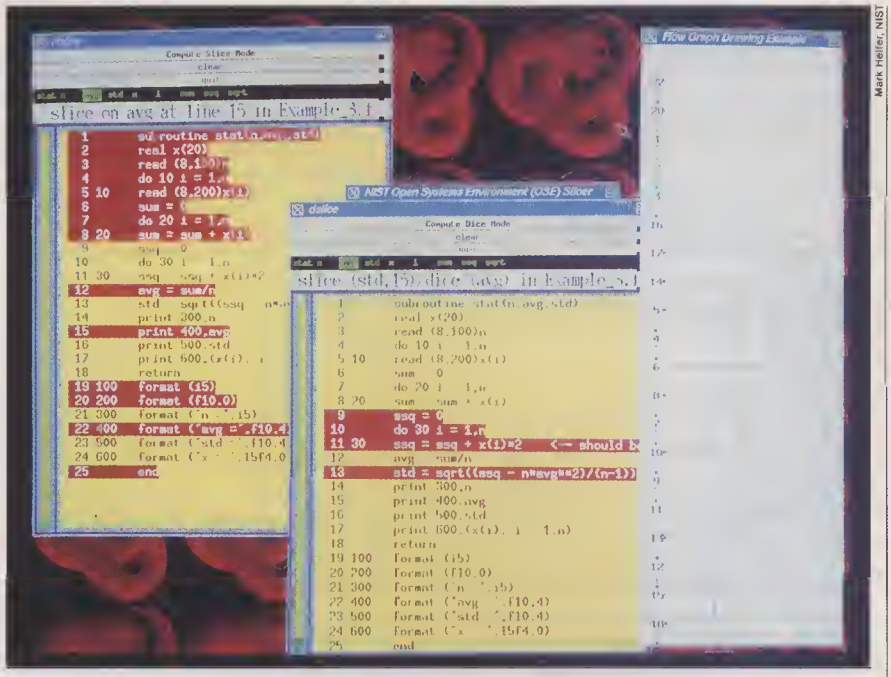
Interoperability standards, though necessary, are not sufficient for a complete open systems environment. An example of this is provided by the X Window System protocol, another *de facto* standard that specifies how graphics primitives can be communicated between an application program and graphics software running on a workstation. The protocol allows, say, an X Window application running on an IBM workstation to interact with a user sitting at a Sun workstation. The interoperability, however, does not mean that the source codes on these two systems are compatible. Each one may use different library functions to generate the X Window protocols.

OPEN SYSTEMS ENVIRONMENT. No single standard provides all the functionality needed in a modern computing environment. To provide portability and interoperability requires a comprehensive set of standards.

The Posix open systems environment (OSE) being put together by Working Group 1003.0 of the IEEE Technical Committee on Operating Systems (TCOS) offers a standard set of interfaces to information systems' building blocks, covering both portability and interoperability standards.

Not all the specifications in the Posix OSE are IEEE Posix (1003.x) standards. Posix functions serve as a basis, supplemented by other applicable open system standards—like those under development by the ISO and ANSI.

Two types of standard interfaces are specified in the Posix OSE: the application program interface (API) and the external environment interface (EEI) [Fig. 1]. The APIs generally are the procedure calls made to the application platform—the computer in which the application program is running and its operating system—for a particular programming language. Through these calls, APIs provide source-code portability.



Mark Helfer, NIST

IEEE portable operating system interface (Posix) standards are being used by a programmer at the National Institute of Standards and Technology, Gaithersburg, Md., to manipulate slices, lines of code that affect the final value of a variable. Highlighted in the leftmost window are all the lines of the program used in generating the output values of "avg" (average). A slice in the center window shows the variable "std" (standard deviation), with lines from the first slice masked. The result shows lines used to compute "std" but not "avg," lines believed to contain an error. The rightmost window graphically illustrates data flow within the slice. Windows and graphics are generated by using the X Window system with a Posix operating system interface; data flow and slicing code was written in ANSI C.

The external environment refers to external entities with which the application platform exchanges information, including the human end-user, hard copy documents, and physical devices such as video displays, disks, printers, and networks. Generally in the form of communication protocols, record and document formats, display formats, and distributed systems services, EEIs, in contrast to APIs, provide mainly for interoperability.

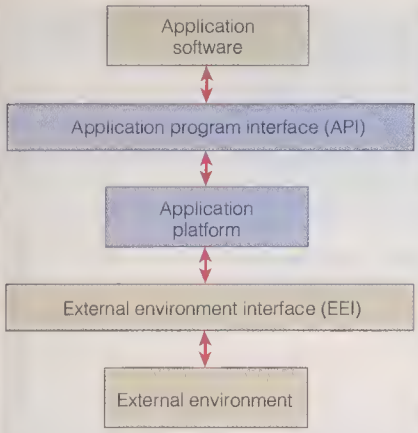
FIVE ROLES. Examining details of the Posix OSE application program interfaces is helpful in exploring how standards can be used in constructing portable software. Based on services they provide, four general categories and a special-purpose category are available. The general categories cater to system, communications, information, and human-computer interaction services. A typical computing environment will require some, but not all, of the standards contained in each of these four categories. A fifth category—domain services—is provided for such special-purpose environments as transaction processing.

System services include both language and operating system services. Language services are the functions typically provided by programming languages such as C, Fortran, Pascal, and others. Operating system services are those used to control the resources of a computer system—hard-disk storage, printer, and so on.

In the language service area standard interfaces specify instructions in different programming languages—Ada, Basic, C, C++, and Pascal (for example, the ISO/IEC 9899 standard for the C language). To make other services in the OSE accessible from application programs, language bindings (subroutine calls in specific languages) are needed for one or more of these languages.

Defining terms

Compiler: a computer program that translates computer code in a high-order language (such as Fortran) into its machine-language equivalent.
Environment services: services related to external objects, such as conditions and processes that influence the behavior of a system.
Interface: a shared boundary across which information is passed.
Kernel: a software module that encapsulates an elementary function or functions of a system.
Language binding: definition of the parameters passed and functions to be performed by a subroutine call for a specific language (C, maybe).
Language services: functions provided by programming languages (basic mathematical functions, for example).
Logical naming: services that allow the use of system resources by name rather than by hardware addresses.
Open system standard: a specification developed in a consensus process, to which any vendor can build products.
Posix standards: a family of open system standards developed by the IEEE Technical Committee on Operating Systems.
Real-time programming: programming for computation to be performed during an external process, so that the computation may be used to respond to the process in a timely fashion.
Software component: a piece of software whose interfaces are precisely defined so that programmers can use it without knowing its structure.
Source code: computer instructions and data definitions expressed in a form suitable for input to an assembler, compiler (see above), or other translator.
Transaction: a data or control element, signal, event, or change of state that causes, triggers, or initiates an action or a sequence of actions.
Utility: a software tool designed to perform a frequently used support function.



[1] The standards being developed under the IEEE portable operating system interface (Posix) open systems environment effort employ this reference model. It includes two important interfaces: an application program interface between the application software and platform, and an external environment interface between the platform and such peripheral systems as printers and displays.

The Posix kernel standard (1003.1), originally defined using C, will soon have Fortran (1003.9) and Ada (1003.5) language bindings. The most common language for Posix interfaces is C, although language-independent bindings (generic subroutine calls not tied to a specific programming language) are now being developed by IEEE Posix working groups.

Among the major categories of operating system services in the Posix OSE are process management, task management (suspension or resumption of a process, for example), and environment services (like obtaining a terminal identification or user profile). Other services include: process communication and synchronization; input/output; file management; event, error, and exception management (enabling and disabling interrupts, for example); time services; and memory management.

Standards in the OSE providing these services include Posix shell and utilities (1003.2), which provides a command language (similar to DOS commands used in IBM PC batch files); software tools for such common operations as sorting; and real-time extensions (1003.4), which handles real-time programming features.

Communications services, including ISO Open Systems Interconnection, make communication possible for application programs running on networked computers. They include services for file transfer, namespace and directory services, network file access, remote procedure calls, protocol-independent network access, and data representation. Both API and EEI functions are included in this area.

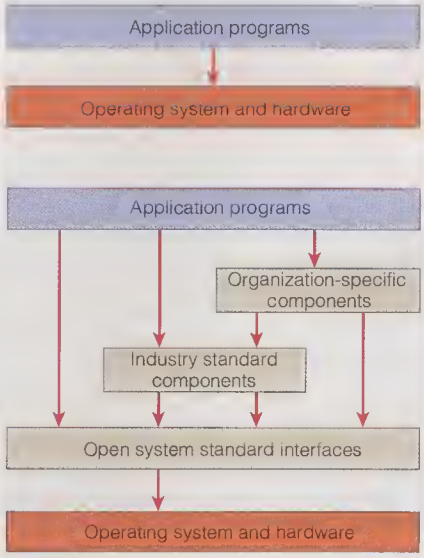
The interface to the interoperability functions is through the standard APIs, such as the protocol-independent interface (1003.12) and the remote procedure call interface being developed by ANSI X3T5.5 working group.

Information services include database services, which provide the capability to store and retrieve data from long-term storage, and data interchange services to exchange data between systems.

Database services are the functions associated with database management systems. These include: data definition and manipulation (the ability to create, update, and delete records, fields, or tables); data access (the ability to retrieve data based on complex search conditions); and data integrity (the locking of data items, transaction control, and synchronous writes—that is, writing of data on an external, backup hard-disk system synchronously with the writing in the main memory).

Application programs use database services extensively, and the APIs in the Posix OSE information services area include such non-Posix standards as Structured Query Language (ISO 9075:1982) and Network Data Language (ISO 8907:1987).

Included in data interchange services are data description protocols, character sets, and data format protocols. Data description protocols provide a standard means of associating a name with individual data elements. Data format protocols add attributes that describe the physical characteristics of the data. Among the standards addressing data interchange services is the Standard Generalized Markup Language (ISO 8879:1986)—again a non-Posix example—useful for defining the layout and structure of a document.



[2] In today's architecture, the application programs operate directly with the designated operating system and hardware (top). Aiming at total portability and interoperability of software, the IEEE Posix open system architecture allows three application program interfaces, each with its own possibility for software components. The first is specific to an organization that uses or designs the software, the second relates to industrywide standard software components, and the third—open system standard interfaces—is designed to work with each of the previous two or directly with the application program (bottom).

The Posix OSE includes national and international electronic data interchange standards being developed for data format protocols—like ISO 9735. Other standards embraced by Posix in the information services category include Computer Graphics Metafile (ANSI X3.122-1986), which provides a standard means for storage and exchange of computer graphics.

HUMAN-COMPUTER INTERFACE. Using the window and mouse style of interaction popularized by the Apple Macintosh, the human-computer interaction services in the Posix standards provide functions for communication between user and computer.

Applicable external environment interface standards will include the X Window protocol, which specifies the format and meaning of messages between an application program and a display terminal, and human factors standards.

In development in this category is the IEEE 1201.2 Drivability Recommended Practice. It will recommend a set of window system behaviors designed to make working with different systems of this kind as easy as driving different makes of automobiles.

API standards in this area are still being defined. Among them is IEEE Standard 1201.1, a standard intended to be a set of window system function calls that can be used with any system that provides the services to create and manipulate menus, buttons, scroll bars, graphics, and other common features of window-based interfaces.

It is doubtful that any information-processing system will implement all the standards included in the Posix open systems environment. A subset of them, referred to as a "profile," is typically sufficient to meet an organization's requirements. Profiles for different types of applications, such as transaction processing, real-time programming, and supercomputing, are being developed within the Posix working groups.

Such profiles are incorporated in the domain services area—the fifth component of the Posix open systems environment. Organizations may also have their own profiles, based on their unique needs. For example, the National Institute of Standards and Technology (NIST) has established an applications portability profile, which some Federal agencies have adopted to promote software portability within the Government.

The widespread interest in open systems has encouraged strong support from computer and software vendors. Most vendors now provide a system compatible with the Posix 1003.1—a basic operating system, or kernel standard, as well as the other, non-Posix completed standards (such as those for programming languages). As other Posix standards are completed in the near future, conforming systems from leading vendors should follow.

When Posix standards for the open systems environment become available, what will be the most effective way of using them to achieve applications portability? One approach is to build components that provide services specific to an industry or an individual organization, resulting in a hierarchy of services. These would include generic system services provided by standards such as the Posix kernel, industry-specific services provided by components built on the system services, and organization-specific services provided by components built on the industry-specific and the generic system services.

Application programs for end-users can then be built for the application program interfaces provided by the hierarchy of components. For example, an organization-specific interface might be a specification for a function that displays a company logo, department name, and time of day on a graphics terminal. A software component to provide the specified service would use operating system functions to obtain the time of day, bitmap for the logo, and department information from a database. Many of the organization's application programs use the same service, and the application programs may run on many different computers.

The application programs call these APIs, rather than calling operating system services directly. This approach is sometimes used today to deal with system dependencies, and it will still be necessary when open system standards are used.

It is also possible to specify an API for a particular industry. For example, NIST and the Interactive Multimedia Association (formerly the Interactive Video Industry Association), Washington, D.C., are developing an API for multimedia services to be used in computer-aided training systems. Components providing the services specified in the API can be built on standard interfaces. Because they are built using open system standards, the components can be ported to diverse hardware at low cost.

In application architecture today, the application software interfaces with the operating system and hardware. Open system standards introduce three layers that will make the portability and interoperability possible—organization-specific APIs, industry standard APIs, and an open system standard interface [Fig. 2].

Open system standards are likely to have a significant impact on both cost and competition in the computer industry. Software products can now be made more efficiently because developers can produce a single version for the standard programming interface rather than a different version for each hardware vendor.

Also, vendors will be able to compete for business that previously was denied to them because of users' dependence on another vendor. When all the Posix standards are completed, users will be able to buy software from different vendors without requiring major conversions of their internally developed software. Since software products will be developed more efficiently for a wider range of hardware, software components will become more economically practical.

Representative IEEE application program interface standards

Standard	Subject	Scope	Status
1003.1	System application program interface (kernel)	Basic operating system services such as file I/O and process control	Complete; became ISO Standard 9945.1 in December 1990
1003.2	Shell and utilities	Command language and utilities that can be used in shell scripts[a] or command procedures	Nearing completion
1003.2a	User portability extension	Utilities for time-sharing systems	Nearing completion
1003.4	Real-time extensions	Real-time programming features such as process locking and synchronization	Nearing completion
1003.4a	Threads extension	Real-time features useful for supporting transaction processing	Nearing completion
1003.5	Ada language binding	1003.1 function calls for the Ada language	Nearing completion
1003.6	Security extensions	Security features such as access control lists and multilevel security	Nearing completion
1003.7	System administration	System management features for such tasks as adding users and checking device status	In progress
1003.8	Transparent (network) file access	Functions for making files on several machines appear to reside on a single machine	In progress
1003.9	Fortran interface	1003.1 function calls for the Fortran language	Nearing completion
1003.12	Protocol-independent network interface	Communication services independent of protocol	In progress
1003.15	Batch scheduling	Functions for batch (noninteractive) processing	In progress
1003.17	Name space and directory service	Distributed systems directory functions	In progress
1201.1	Window-based user interface	Window system, graphical user interface functions	In progress
1224	X.400 message-handling interface	Open systems interconnection (OSI) electronic mail services	In progress
1238.0	Support functions	Common OSI support functions for lower-level interface	In progress
1238.1	File transfer access method	OSI file transfer functions	In progress

[a]Shell scripts: commands similar to DOS commands used in IBM PC batch files.

TO PROBE FURTHER. UniForum, the international association of Unix systems users, publishes a series of booklets entitled "Posix Explored." Contact UniForum, 2901 Tasman Dr., Suite 201, Santa Clara, Calif. 95054; 408-986-8840.

The Posix 1003.1-1990 (kernel) standard is available from IEEE Publications, which can be reached at 800-272-6657. IEEE Standard 1003.1–1990 is also referenced as ISO/IEC 9945–1:1990.

The National Institute of Standards and Technology Special Publication, "Application Portability Profile—APP—the U.S. Government's Open System Environment Profile OSE/1 Version 1.0" (Order No. SN: PB91-201004), explains Posix and other open system standards. It is available from the National Technical Information Service, 5285 Port Royal Rd., Springfield, Va. 22161; 703-487-4650.

"The Guide to Posix Open Systems Environment IEEE 1003.0," currently in draft form, should be available from the IEEE Service Center in 1992.

The seven-layer, open-systems interconnection model is discussed in detail in "Helping computers communicate," *IEEE Spectrum*, March 1986, pp. 61–70.

ABOUT THE AUTHOR. D. Richard Kuhn is a computer scientist at the National Institute of Standards and Technology, Gaithersburg, Md., where his responsibilities include operating system interface standards, formal methods, and computer security. He received an M.S. in computer science from the University of Maryland in College Park. ◆

Awards/91

IEEE service awards and prize papers

Thelma Estrin (LF) received the Haraden Pratt Award "for IEEE leadership, strengthening the Institute's technical and professional programs, and her exemplary role in promoting the recognition of women in engineering."

Estrin, professor of computer science at the University of California at Los Angeles (UCLA) and a consultant to private industry and government, received B.S., M.S., and Ph.D. degrees in electrical engineering from the University of Wisconsin. In 1961 she joined the staff of the Brain Research Institute at UCLA, where she developed the first integrated computer-based laboratory for neuroscientists.

From 1975 to 1980 she headed the IEEE Committee on Professional Activities for Women, starting in 1976 a program to push the 5Rs for women: recruitment, retention, retraining, redress of grievances, and re-education of the profession.

Stephen J. Kahne (F) received the Richard M. Emberson Award "for distinguished service leadership in the Institute's technical and education programs, and for contributions to the field of control systems engineering."

Kahne, chief scientist, Mitre Corp.'s Washington (D.C.) Group, earned his BEE at Cornell University, Ithaca, N.Y., and M.S. and Ph.D. in electrical engineering from the University of Illinois, Urbana–Champaign. As a commissioned officer in the U.S. Air Force in the early 1960s, he helped found the Control and Information Systems Laboratory at the National Aeronautics and Space Administration's Electronic Research Center, Cambridge, Mass.

Kahne has held about 50 volunteer positions in the IEEE, including editor of the *IEEE Transactions on Automatic Control*, president of the Control Systems Society, and Vice President–Technical Activities in 1984 and 1985.

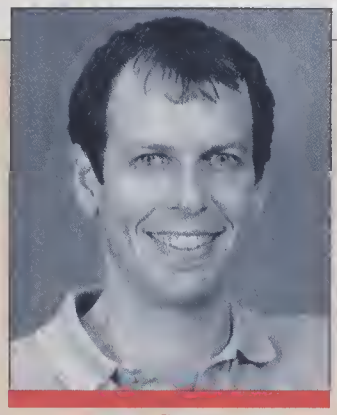
John C. Doyle, Keith Glover (SM), **Bruce A. Francis** (F), and **Pramod P. Khargonekar** (SM) received the W.R.G. Baker Prize Award for their paper, "State-Space Solutions to Standard H_2 and H Control Problems," published in the August 1989 issue of *IEEE Transactions on Automatic Control*.

Doyle is associate professor of electrical engineering at the California Institute of Technology in Pasadena. He obtained his B.S. and M.S. degrees in electrical engineering from the Massachusetts Institute of Technology in Cambridge, and the Ph.D. in mathematics from the University of California at Berkeley. His interests include modeling and control of nonlinear systems.

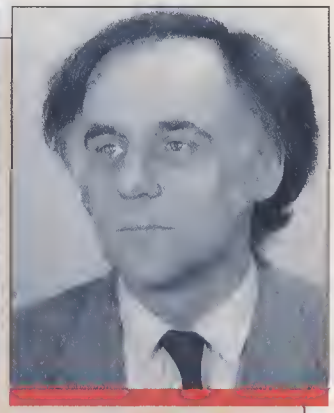
Glover is professor of electrical engineering at the University of Cambridge in the United Kingdom. He received the B.Sc. degree in engineering from Imperial College in London and the S.M., E.E., and Ph.D. degrees from the Massachusetts Institute of Technology. His interests include linear systems and identification.

Francis, professor of electrical engineering at the University of Toronto in Canada, obtained his B.A.Sc. and M.Eng. degrees in mechanical engineering and his Ph.D. degree in electrical engineering from the University of Toronto. His current research involves analysis and design of computer-controlled systems.

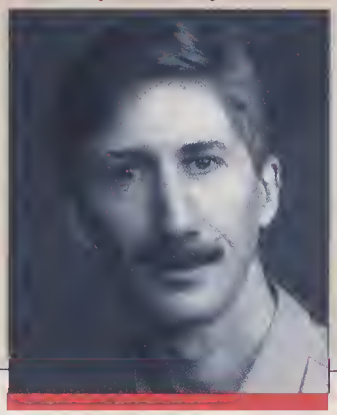
Khargonekar is professor of electrical engineering at the University of Michigan, Ann Arbor. He received his B. Tech. degree in electrical engineering from the Indian Institute of Technology, Bombay, and an M.S. degree in mathematics and a Ph.D. degree in electrical engineering from the University of Florida in Gainesville. His current interests include robust and optimal control.



John C. Doyle



Keith Glover



Bruce A. Francis

Pramod P. Khargonekar

Tadao Murata (F) received the Donald G. Fink Prize Award for his paper "Petri Nets: Properties, Analysis and Applications," published in the April 1989 issue of the *Proceedings of the IEEE*.

Murata is professor of electrical engineering and computer science at the University of Illinois in Chicago. He received the M.S. and Ph.D. degrees in electrical engineering from the University of Illinois, Urbana–Champaign.

He initiated the state equation and invariance theory for Petri nets and applied them for deadlock detection in Ada programs, fairness problems in concurrent systems, and performance evaluation in distributed systems. More recently, he applied Petri nets to modeling and the analysis of logic programming and artificial intelligence.

Currently Murata serves as an editor for the *IEEE Transactions on Software Engineering* and as an associate editor for the *Journal of Circuits, Systems and Computers*.

Keshab K. Parhi (M) received the Browder J. Thompson Memorial Prize Award for his paper "Algorithm Transformation Techniques for Concurrent Processors," published in the December 1989 issue of the *Proceedings of the IEEE*.

Parhi is assistant professor of electrical engineering at the University of Minnesota in Minneapolis. He received the B. Tech. (Honors) degree from the Indian Institute of Technology, Kharagpur, the M.S.E.E degree from the University of Pennsylvania in Philadelphia, and the Ph.D. degree from the University of California in Berkeley. His research interests include signal and image processing systems.

He is an associate editor for image processing and very large-scale integration (VLSI) applications for the *IEEE Transactions on Circuits and Systems*. He is also a member of the VLSI systems and applications technical committee of the IEEE Circuits and Systems Society and a member of the VLSI technical committee of the IEEE Signal Processing and Computer Societies.

IEEE Engineering Leadership, Corporate Innovation Awards

Seymour R. Cray received the IEEE Engineering Leadership Recognition "for exceptional personal leadership in the design and construction of the world's highest performance general-purpose supercomputers."

Cray is president and founder of Cray Computer Corp., Colorado Springs, Colo. He earned a B.S. degree in electrical engineering from the University of Minnesota in Minneapolis. In 1972 he founded Cray Research Inc. to design and build the world's highest performance general-purpose supercomputers. The result was the CRAY-1 supercomputer, introduced in 1976, and the CRAY-2 supercomputer, introduced in 1985.

Cray has invented a number of technologies that have been patented by the companies for which he has worked. Among the more significant are the CRAY-1 vector register technology, the cooling technologies for the CRAY-2 computer, and the CDC 6600 Freon-cooling system.

Apple Computer Inc., Cupertino, Calif., has won the IEEE Corporate Innovation Recognition "for the creation and establishment of the broadly successful personal computer."

Founded in 1976 in a garage in Cupertino by Stephen G. Wozniak and Steven P. Jobs, the company pioneered in the home computer industry. Its first computer, the Apple I, was available only as a kit, but the two computer whizzes soon followed it with the technically superior Apple II. Apple then began the marketing drive that eventually made its name a household word as it sold some 5 million Apple II and 3 million Macintosh computers. Annual sales are well over US $5 billion.

On Oct. 15, 1990, the company introduced three new entry-level Macintosh personal computers—the Classic, the LC, and the IIsi—which put much of the power of the company's most advanced computers into its least expensive ones. It also continues to supply higher-end modular personal computers—the IIcx, the IIci, and the IIfx.

EEs' tools & toys

Years on the far side

Any fan of Gary Larson's cerebral humor and out-there nerdy kids, bespectacled scientists, and philosophical animals will thrill to know that "The Far Side Computer Calendar" is available in software. A typical example: two cows sitting on the living room sofa with one remarking to another, "There goes the telephone again and here we sit without opposable thumbs."

You can justify its US $69.95 suggested retail price because it is a perpetual calendar and full-featured desktop organizer complete with an appointment book that has audio alarms and the ability to program recurring events. But the real reason for getting it is that you're never allowed to forget it's there. You have constant reminders such as a flock of surly penguins on an ice floe floating across your spreadsheet or a meteorite crashing through your engineering analysis.

Amaze Inc. of Kirkland, Wash., produces versions of the calendar in full-color, high-resolution animation for both the Macintosh and PC-compatible machines. Those with older DOS machines take note, though: the progam requires Microsoft Windows 3.0 or higher, plus a hard disk.

Why did Gary Larson go on computer? Among other reasons, he noted, "the Amaze people *themselves* seemed to have an uncanny resemblance to some of the characters I draw. I was convinced this was a 'marriage' of destiny." *Contact: Amaze Inc., 11810 115th Ave. N.E., Kirkland, Wash. 98034-6923; 206-820-7007; fax, 206-823-0568;* **or circle 104.**

AUDIO

Music of the spheres on record

Lovers of offbeat music might enjoy listening to radio signals emanating from space that have been intentionally shifted here on earth into the audio range. Originally, astronomer Fiorella Terenzi thought the shift might help her in her research in acoustic astronomy. But then the possibility of using it commercially reared its head. Now her sounds—from radio galaxy UGC 6697, which is 1.7 quadrillion kilometers (180 million light years) away from earth, are available on audiocassette tape and compact disc as "Music from the Galaxies."

Radio signals from UGC 6697 emanating at 0.6, 1.4, and 5 GHz, and spectral and other data were collected by telescopes in New

The picture on the compact-disc cover shows Fiorella Terenzi during a performance of galactic music. The cassette tape cover illustrates radio telescopes collecting data from space.

Mexico and Arizona in the United States, Germany, and Chile. Terenzi translated the signals into sound within hearing range (between 20 and 20 000 Hz), employing tools from the Computer Audio Research Laboratory and a program she designed in CMusic, a sound synthesis language.

UGC 6697 is an irregular galaxy that contains a circular ring of ionized gases. It presents a "peculiar" radio source, according to Terenzi, that seems due to dynamic interaction between the galaxy and the intergalactic medium.

The six excerpts of transcribed data recorded in "Music from the Galaxies" sound like science fiction movie soundtracks. In some, familiar sounds and noises are discernible—like the deep breaths in "Sidereal Breath," several out-of-tune basses in "Galactic Beats," or a tropical jungle full of noisy birds and animals in "Collision." In others, the sounds are more unusual. In "Cosmic Time," for instance, Terenzi laid an original score based on translated signals over a soundtrack of transcribed galactic sounds. The score is performed by a synclavier imitating violins, drums, and a saxophone.

The 40-minute tape and compact disc, distributed by Island Records (Catalog No. 422-848-768-2/4), are available in record stores for US $8 to $14. *Contact: David Reisner, Terenzi Music, Box 34182, Los Angeles, Calif. 90034-0182; 213-207-3004.*

SOFTWARE

Gourmet circuitry

Need peppier analog circuits? *The Spice Cookbook*, the third in a series of Intusoft's reference guides, contains more than 100 simulation examples using practical analog circuits. To assist users in modeling and simulating circuits, each example includes a complete technical overview with related equations, background information, circuit schematics, associated IsSpice netlist, and output graphs. Among the topics covered are analog and digital techniques, analog computing, continuous and discontinuous systems, and high frequency and microwaves.

A separate Circuit Specifics section covers circuit initialization, convergence, IsSpice syntax pitfalls, device modeling, and circuit partitioning. Basic programs are included to enhance circuit descriptions.

The 250-page volume, available for US $50, contains all the schematics (SpiceNet), circuit netlists (IsSpice), and Spice models included in *The Spice Cookbook*. Educational discounts are available. *Contact: Charles Hymowitz, Intusoft, Box 710, San Pedro, Calif. 90733-0710; 213-833-0710; fax, 213-833-9658;* **or circle 105.**

One-stop shopping

For engineers who have little time to shop for software, TechExpress Inc.'s electronic bulletin board can provide fast access to software specifications, demo disks, and catalog and purchasing information 24 hours a day.

A distributor of technical and engineering software, TechExpress offers DOS and Macintosh products for circuit board layout and routing, schematic capture, digital and analog simulation, and thermal analysis. It also supplies math and graphics packages, Lotus add-ons, and flow charts. The software includes Derive, Matlab, Mathematica, Graftool, Pspice, Susie, McCAD, Schema, and Gerbtool. For access, call 818-707-2540 with a modem set to 8 bits, one stop bit. There is no parity for access to the bulletin board service. For a free catalog, call 800-743-7074. *Contact: TechExpress Inc., 31200 La Baya Dr., Suite 301, Westlake Village, Calif. 91362; 818-707-7074;* **or circle 106.**

COORDINATOR: Dana Norvila
CONSULTANT: Paul A.T. Wolfgang, Boeing Computers

Program notes

(Continued from p. 19)
for the platform.

SPAG by Polyhedron Software Ltd., Standlake, the United Kingdom, is one product that restructures Fortran source code. Polyhedron advertises it as "the spaghetti unscrambler," showing translation from unstructured Fortran 66 code to structured Fortran 90. It also sells versions of SPAG that convert from Fortran 66 and 77 and from IBM and VAX Fortran into Fortran 90, so Fortran source code written for one platform can be quickly moved to another platform.

Programs often contain so-called dead code, which can never be executed, and variables or parameters, which are declared but never used. SPAG 3.0 (the latest version) identifies this type of clutter and optionally allows the user to remove it. Conversely, SPAG explicitly declares those variables that are not formally declared, as is often the case with older Fortran codes that use implicit typing.

For more on SPAG, contact Polyhedron Software Ltd., Linden House, 93 High St., Standlake, Witney, OX8 7RH, United Kingdom; (44+865) 300 579; **or circle 103.**

Finding lost children

Programmers can put different spins on scanned images to produce surprising results. With software tools that exploit these techniques, an anthropologist can put "flesh" on the "skull" of a prehistoric man, or a plastic surgeon can preview the results of surgery. Another application for this technology is to age individuals electronically by altering existing photos.

At the National Center for Missing and Exploited Children, Arlington, Va., the technology is being used to turn family photos of young children into missing posters showing the child today.

Pictures generated by a prototype aging workshop have led to the identification of seven missing children in the past 12 months. How accurate are pictures generated by the workstation? Well, one of the children found had been missing for 11 years.

This is expensive technology, however: millions of U.S. dollars are needed to place aging workstations at major police departments around the country. To raise money for workstations, Micrografx, a Richardson, Texas, company specializing in graphics software for Windows and OS/2, decided to find corporate and individual sponsors for its 1991 Comdex Chili Cookoff and donate all proceeds to the Center. Micrografx was able to raise almost $1 000 000 to purchase computer tools for the Center. It estimates the money will reunite over a hundred children with their parents next year. *Contact: Pat Laroche, Micrografx, 1303 E. Arapaho Rd., Richardson, Texas 75081; 214-497-6183; or the National Center for Missing and Exploited Children, 2101 Wilson Blvd., Suite 550, Arlington, Va. 22201; 703-235-3900.*

COORDINATOR: Gadi Kaplan
CONSULTANTS: Stuart Feldman, Computer Systems Research, Bellcore, and John Kellum, Intergraph Advanced Processor Division

National Center for Missing and Exploited Children

A mix of science and art—facial growth data and heredity factors based on parents' photos—are at the heart of computer programs at the National Center for Missing and Exploited Children, Arlington, Va., that "age-progress" photos of missing children such as the two-year-old shown on the left. The age-progressed photo (center) resembles that of the found child at seven.

1991 Index
IEEE Spectrum
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This index covers all technical items — papers, correspondence, reviews, etc. — that appeared in this periodical during 1991, and items from previous years that were commented upon or corrected in 1991.

The *Author Index* contains the primary entry for each item, listed under the first author's name, and cross-references from all coauthors. The *Subject Index* contains several entries for each item under appropriate subject headings, and subject cross-references.

It is always necessary to refer to the primary entry in the *Author Index* for the exact title, coauthors, and comments/corrections.

AUTHOR INDEX

+ Check author entry for coauthors

† Check author entry for subsequent corrections/comments

+ Check author entry for coauthors

SUBJECT INDEX

† Check author entry for subsequent corrections/comments

+ Check author entry for coauthors

† Check author entry for subsequent corrections/comments

+ Check author entry for coauthors

Employment opportunities

Organizations seeking engineers and scientists describe their various openings in the following advertising section

In order to conform to the Age Discrimination in Employment Act and to discourage age discrimination, IEEE may reject any advertisement containing any of these phrases or similar ones, "recent college grads," "1–4 years maximum experience," "up to 5 years experience," or "10 years maximum experience." IEEE reserves the right to append to any advertisement, without specific notice to the advertiser, "Experience ranges are suggested minimum requirements, not maximums." IEEE assumes that, since advertisers have been notified of this policy in advance, they agree that any experience requirements, whether stated as ranges or otherwise, will be construed by the reader as minimum requirements only. While IEEE does not ban the use of the term "entry level," its use is discouraged since, to some, it connotes an age rather than an experience designation. IEEE accepts employment advertising to apprise its members of opportunities. Interested parties should be aware that the political and humanistic values of certain advertisers may differ from their own. IEEE encourages employers to offer salaries that are competitive, but occasionally a salary may be offered that is significantly below currently acceptable levels. In such cases the reader may wish to inquire of the employer whether extenuating circumstances apply.

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The following listings of interest to IEEE members have been placed by educational, government, and industrial organizations as well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum* Magazine, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

Academic Positions Open

Arizona State University seeks Scientist/Engineer to manage the staff and operations of the research laboratories of the Center for Solid State Electronic Research. The Center is a shared resource research center in the College of Engineering at Arizona State University. Laboratories in the Center include a 4000 sq. ft. clean room, semiconductor processing equipment, MBE laboratory, optical characterization and electrical characterization labs, X-ray topography, SEM's, mask making facility, and a computational microelectronics laboratory. Research and teaching opportunities are also available. Requires Ph.D. degree in electrical engineering or physics, with 3 years experience in directly relevant field. Applicant must be directly familiar with semiconductor processing and cleanroom facilities, and have characterization experience. Salary negotiable depending upon experience and qualifications. Application deadline November 15, 1991, or on the 15th monthly until filled. Send resume to Dr. L. Akers, Director, Center for Solid State Electronics Research, Arizona State University, Tempe, AZ 85287-6206. Arizona State University is an equal opportunity, affirmative action employer.

Faculty Position in Devices-Caltech. The Electrical Engineering program at Caltech invites applications for a tenure-track position as assistant professor. The term of the initial appointment is normally four years, and is contingent on completion of Ph.D. requirements. Exceptionally well qualified applicants may also be considered at the assistant for full professor level. Candidates with interests in electronic, magnetics, acoustic, optical, or superconducting devices, and sensors, are encouraged to apply. We are seeking a highly qualified can-

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didate who is committed to a career in research and teaching. Interested applicants should submit a resume with the names and mailing addresses of at least three references to Professor David Rutledge, Department of Electrical Engineering, California Institute of Technology, Pasadena, CA 91125. Caltech is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply.

The Mechanical Engineering Department at Carnegie Mellon University invites applications for tenure-track positions at the Assistant Professor level commencing September 1992 in the following areas: 1. Robotics and Controls (2), 2. Solid Mechanics (1). One of the controls positions is joint with the Robotics Institute at Carnegie Mellon. Applicants must have a Ph.D. in Mechanical Engineering (or closely related field). Duties include teaching undergraduate and graduate courses, and research. Appointments at a higher rank will be considered for qualified applicants having a proven record of grant support. Submit application, complete resume, and names of three references to Professor G.B. Sinclair, Mechanical Engineering Department, Carnegie Mellon University, Schenley Park, Pittsburgh, PA 15213-3890. Closing date for applications is January 31, 1992. Carnegie Mellon University is an affirmative action/equal opportunity employer.

University of Illinois at Chicago. Instructorships and tenure-track faculty positions in electrical engineering and computer science at both the junior and senior level are available. Rank and salary commensurate with qualifications. An earned Doctorate in EE or CS must be completed by date of appointment, but not for the instructorships. Demonstrated teaching and research abilities are highly desirable. For full consideration, please send resume, list of publications, and the names of at least three references by April 30, 1992 to Dr. Wai-Kai Chen, Head, Department of Electrical Engineering and Computer Science (M/G 154), University of Illinois at Chicago, P.O. Box 4348, Chicago, IL 60680. The University of Illinois is an Affirmative Action/Equal Opportunity Employer.

Electrical Engineering: The University of Portland seeks candidates for tenure track positions at the rank of Assistant/Associate Professor. Dedication to excellence in teaching is essential. Ph.D. in Electrical Engineering is required. The candidates are expected to teach undergraduate and graduate courses and to conduct professional activities in at least one of these areas: Microelectronics, VLSI design, Communication Systems, Optics and Optoelectronics. Send resume and names of at least three references to Dr. Aziz S. Inan, Chair, Electrical Engineering, University of Portland, 5000 N. Willamette Blvd., Portland, OR 97203. (503)283-7314. An affirmative action/equal opportunity employer.

The Bradley Department of Electrical Engineering of Virginia Polytechnic Institute and State University invites applications for several tenure track faculty positions. Greatest needs are in the areas of communications with emphasis on high frequency electronics, computers, fiber optics, and signal processing. Consideration will be given to applicants in all areas at the Assistant and Associate Professor level. Applicants must have an earned doctorate, be interested in undergraduate and graduate teaching, and be willing to secure research sponsorship. Virginia Tech is Virginia's land grant university offering degrees through the Ph.D. Send complete resume with references and employment/citizenship status to: Prof. W.L. Stutzman, Chairman, Faculty Search Committee, Bradley Department of Electrical Engineering, Virginia Tech, Blacksburg, VA 24061-0111. Applications will be accepted until April 15, 1992, or until suitable candidates are selected. Virginia Tech is an Equal Opportunity/Affirmative Action Employer and welcomes applications from minorities and women.

Southern Methodist University, School of Engineering and Applied Science. Department Chair, Computer Science and Engineering. Nominations and applications are invited for the position of Professor and Department Chair of the Department of Computer Science and Engineering at Southern Methodist University. Applicants must have a Ph.D. in Computer Engineering, Computer Science, or a related discipline. Candidates must have demonstrated excellence in research with a substantial grant record and a strong commitment to teaching. It is anticipated that the position will be filled by August, 1992. SMU is a private university in Dallas, Texas with approximately 8,000 students. CSE is in the School of Engineering and Applied Science, where a close working relationship exists with the Department of Electrical Engineering. The department is growing and presently has fourteen faculty positions. CSE presents a balanced program of research and education at all levels and has been offering Ph.D. degrees since 1970. The department has extensive contacts with computer and telecommunications related industrial organizations. The Dallas area is traditionally distinguished as one of the top five centers for high technology complemented by the presence nearby of the Superconducting Super Collider. Applicants should send a complete resume, including the names of three references to: Professor Ian Gladwell, Chair, CSE Search Committee, 208 Clements Hall, Southern Methodist University, Dallas, TX 75275. SMU is an equal opportunity/affirmative action, Title IX employer. Applications from women and minorities are particularly encouraged. Applications will be accepted until February 1, 1992.

Head, Dept. of Electrical and Computer Engineering Carnegie Mellon University. Nominations/Applications are invited for the position of the Head of the Department of Electrical and Computer Engineering at Carnegie Mellon University. Currently, the department has 35 faculty members, 160 Ph.D. students, 90 M.S. students, and 400 undergraduate students. With a newly developed, highly flexible B.S. degree program in Electrical and Computer Engineering, the department is a leader in engineering curricular reform and innovation. The

Leadership in engineering is an Arizona tradition.

Honeywell IAC, 1986

Hopi Pattern Mathematics, 6th century

As an Industrial Fellow at ASU, Mike Wall earned his master's degree while working for a major corporation. It's a unique opportunity, continuing a tradition of engineering excellence that began here hundreds of years ago.

Program sponsors include Motorola (GEG, SPS), Honeywell (CFSG, IAC, and SSO), Intel, McDonnell Douglas Helicopter and U.S. West Small Business Services. They're helping engineers like Susan Ferreira invest in the future.

Hohokam Acid-Based Etching, 10th century

Motorola GEG, 1989

Intel, 1991

Sinaguan Metate Manufacturing, 13th century

In the next two years, Kim Greene will be able to complete an advanced degree and earn over $50,000 in salaries, awards and benefits. She'll also participate in one of the nation's top leadership development programs for engineers.

Opportunities are available in computer science, or chemical, electrical, industrial or mechanical engineering. U.S. citizenship required.

Call **602-965-2276**
or write for more information.
1992 program applications are due by November 25, 1991 (early bird) or January 6, 1992 (final).

Industrial Fellows Program
ARIZONA STATE UNIVERSITY
College of Engineering and Applied Sciences
Tempe, Arizona 85287-7406
(602) 965-2276 FAX (602) 965-2267

Senior Electrical Engineer

Harza, an international consulting engineering firm, has an opening for a Senior Electrical Engineer with a minimum of ten years experience in the design and implementation of computer based SCADA and distributed control systems in the power and process industry.

▼

Responsibilities will include preparing designs, drawings and specifications for computer based SCADA/distributed control systems for Irrigation and Hydro power applications. Will also provide technical assistance and management support to the project team during implementation of the project.

Experience should include knowledge of computer protocols, local and wide area networks, communication systems, and instrumentation used in power, hydro-meteorological and process industry. Strong project management and support background and excellent verbal and written communication skills essential. Some international travel required.

▼

We are an employee-owned firm offering competitive salaries and benefits. Qualified candidates should send their resume with salary history and requirements, in confidence to: Harza Engineering Company, Human Resources Department, Advertisement-20, 233 S. Wacker Drive, Chicago, Illinois 60606. An Equal Opportunity Employer M/F/H/V.

HARZA

Electrical Engineer

Brookhaven National Laboratory's Relativistic Heavy Ion Collider (RHIC) Project has a challenging opportunity for an Electrical Engineer. RHIC will be a world-class particle accelerator where researchers will study fundamental properties of matter under conditions that have not yet existed since the beginning of the universe.

Requirements include a BS/MSEE and a minimum of 10 years' experience in the design of computer-based acquisition and control systems. Proficiency in both hardware and software aspects of these systems required. Background in IEEE-488 based instrumentation and experience with high current precision power supplies are required; knowledge of CAD and circuit analysis programs is a plus.

Brookhaven offers a superior working environment and excellent benefits. Please send your resume, referring to position #NS0945S, to Nancy L. Sobrito, Brookhaven National Laboratory, Associated Universities, Inc., Personnel Division - Bldg. 185, Upton, NY 11973. Equal opportunity employer M/F/H/V.

BNL BROOKHAVEN NATIONAL LABORATORY ASSOCIATED UNIVERSITIES, INC.

Dean
School of Engineering

The University of Dayton invites applications and nominations for the position of Dean of the School of Engineering. The University is seeking to fill this position by July 1, 1992.

The University: The University of Dayton, a Catholic co-educational institution founded by the Society of Mary (the Marianists) in 1850, offers a wide variety of undergraduate programs as well as numerous master and several doctoral programs. The University enrollment of nearly 11,000 students includes over 6,000 full-time undergraduates.

The Position: The School of Engineering has programs in undergraduate engineering and engineering technology and both master and doctoral programs in engineering with a total enrollment of 1,800. The Dean is to provide leadership for a school that is committed to excellence in teaching, research, scholarship, and service to the community.

Qualifications: Candidates for the position should possess the background required for a tenured professorship within the School. This includes an earned doctorate, evidence of scholarly and research accomplishments, demonstrated teaching effectiveness at both the undergraduate and graduate levels, and a record of external financial support for research and/or educational purposes. Candidates should also have experience in administration in which they developed and demonstrated leadership, managerial, and communicative skills.

Nominations and Applications: Applications should include: 1) a letter briefly detailing accomplishments in the area of academic administration, research and teaching, 2) a completed curriculum vitae and 3) names of three references. The University seeks the applications of minorities and women. Please submit applications and nominations by January 20, 1992. Nominations and applications should be mailed to: Dr. James A. Snide, Chair, Search Committee for Dean, School of Engineering, Box 1634, University of Dayton, Dayton, Ohio 45469-1634

The University of Dayton

The University of Dayton is an Equal Opportunity/Affirmative Action Employer

The XEROX Chair for Image and Document Systems
Center for Imaging Science
Rochester Institute of Technology

An endowed chair has been created in the Center for Imaging Science by Xerox Corporation to enable the Center to establish an academic leadership position in the digital imaging revolution which is occurring in the modern business environment. Examples of this revolution can be found in fields which span electronic photography, electronic pre-press, desktop publishing, and digital printing and reprographics. The Center wishes to attract a recognized scholar and researcher in the field to fill this chair as soon as possible. The Center already has faculty expertise in areas related to this field, such as image processing, scanned and sampled imagery, color science and electronic printing. This Chair will allow the Center for Imaging Science to extend its existing strengths in fields wherein images are digitally stored, organized, indexed, retrieved, and communicated. As well as being recognized for appropriate skills, nominees should develop broad research and academic programs in the field, and thus leadership skills are essential for the position. RIT has a history of having a strong undergraduate program, and it is expected that the successful candidate will have a commitment to both graduate and undergraduate education.

Rochester Institute of Technology is an independent, co-educational university enrolling 13,000 students. The Center for Imaging Science grants BS, MS and PhD degrees in Imaging Science and an MS degree in Color Science. RIT is located near the research laboratories of many large and small corporations, including Xerox and Kodak. Imaging has been identified as a strategic thrust of RIT as a whole, and the graduate faculty of the Center for Imaging Science includes faculty from computer science, microelectronic engineering, electrical engineering, physics and chemistry. As part of this emphasis a new 70,000 sq. ft. building was dedicated in 1989 and a PhD program in Imaging Science established in 1990. Nominations and applications should be forwarded to: **Dr. Rodney Shaw, Director, Center for Imaging Science, Rochester Institute of Technology, P.O. Box 9887. Rochester, NY 14623.**

The search for a suitable candidate has recently been reopened, and the search committee will continue to solicit applications until a suitable candidate is appointed.

department has an annual research budget of $13.5 million and is home to: an NSF Engineering Research Center in Data Storage Systems, the SRC-CMU Research Center for Computer-Aided Design, the Pennsylvania SEMATECH Center of Excellence (SCOE) for Rapid Yield Learning, the Center for Excellence in Optical Data Processing (CEODP), the Center for Dependable Systems (CDS), the Laboratory for Automated Systems and Information Processing (LASIP), and a concentrated research effort in Solid State Materials and Devices. The department also has strong research ties to the School of Computer Science, the Robotics Institute and the other CMU NSF Engineering Research Center, the Engineering Design Research Center (EDRC). The research facilities available include extensive computational facilities including access to several supercomputers at the Pittsburgh Supercomputing Center, a 4000-square feet class 100 clean room, recently renovated Solid State Research Laboratories, Data Storage Systems laboratories as well as Optical and Digital Processing laboratories. The successful candidate should have an earned Ph.D. in Electrical/Computer Engineering or related fields, an internationally recognized research stature and the experience and abilities to lead the teaching and research excellence of the department. Nominations/Applications, along with a vita and the names, addresses and phone numbers of three references should be sent to: Professor B.V.K. Vijaya Kumar, Chairman, ECE Department Head Search Committee, Department of Electrical and Computer Engineering, Carnegie Mellon University, Pittsburgh, PA 15213-3890. The search committee will consider all applications and nominations received up to February 1, 1992. Carnegie Mellon University is an affirmative-action, equal opportunity employer.

Gonzaga University in Spokane, Washington is seeking a faculty member with expertise in the areas of Electro-magnetics, Electronics and materials. Responsibilities include teaching in an ABET accredited BSEE program and an MSEE program. Preference will be given to an individual with some industrial design experience. An appointment will be made at the assistant or associate professor level unless the preferred candidate is exceptionally well qualified. Only permanent residents and citizens of the United States will be considered. Candidates must have or have nearly completed a Ph.D. degree by the appointment date. Gonzaga University is a Catholic, Jesuit institution with a commitment to teaching humanistic values to develop the whole person. The attractive, growing campus is set in an area of scenic beauty in the Inland Northwest. Send resume and list of three references to Dr. R.A. Birgenheier, Chairperson, Department of Electrical Engineering, Gonzaga University, 502 E. Boone St., Spokane, WA 99258. Screening of applicants will begin January 2, 1992 and the expected appointment date is August 30, 1992. Gonzaga is an Equal Opportunity/Affirmative Action Employer.

Loyola College in Maryland: The Department of Electrical Engineering and Engineering Science has a tenure-track position at the assistant professor level available Fall 1992. Candidate should have a Ph.D. in Electrical/Computer Engineering and a commitment to excellence in teaching as well as continuing research. Experience in digital systems, control theory, and engineering design is desired, although qualified applicants in other areas will be considered. The Department offers an ABET-accredited Bachelor of Science in Engineering Science Degree with concentrations in electrical science, digital science, and materials science. The Department is in the process of developing a Bachelor of Science in Electrical Engineering Degree program; the first BSEE degrees were awarded in May 1991. In addition, the Department jointly offers, with the Computer Science Department, a graduate program leading to a Master of Engineering Science with concentrations in electrical engineering, computer engineering, and computer science. Loyola College is a private, comprehensive university, with a strong tradition in the liberal arts and is located in suburban Baltimore. Send resume

IEEE discourages age discrimination. Experience ranges are suggested minimum requirements, not maximum.

CLASSIFIED

to: Dr. Paul Coyne, Jr., Chair, Department of Electrical Engineering and Engineering Science, Loyola College, 4501 N. Charles Street, Baltimore, MD 21210-2699. EOE.

San Jose State University Electrical Engineering Department. Applications are invited for entry-level tenure-track faculty positions at the Assistant Professor rank. Positions are available in computer and multiprocessor design, microprocessor applications; microelectronic VLSI/ULSI circuit design; semiconductor devices and technologies; circuits, systems and computer communications networks. Earned doctorate in Electrical Engineering is required. Positions are limited to U.S. citizens or permanent residents. Research, consulting and summer employment opportunities are available. The University is the oldest and one of the largest in the California State University System. It is located at the southern end of San Francisco Bay in the heart of Silicon Valley. Resume and names and addresses of three references should be submitted to Dr. Ray R. Chen, Chair, Department of Electrical Engineering, San Jose State University, San Jose, California, 95192-0084. San Jose State University is an equal opportunity/affirmative action/Title IX employer. Women and minorities are especially encouraged to apply.

The Department of Electrical Engineering and Computer Engineering invites applications for several anticipated tenure-track faculty positions. Applicants at all ranks will be considered. Starting dates are negotiable with preference given for fall 1992. Primary needs are for specialization in the areas of communications, signal processing, controls, computer networks, distributed computing, data communications, microelectronics and VLSI design. Responsibilities include teaching, research and outreach. Salary and rank are commensurate with qualifications and experience. Requirements include a doctorate degree with a demonstrated potential for success in research and a commitment to teaching. Applicants should send a resume with a statement of teaching, research, and outreach interests, as well as a list of at least three (3) references to: Chairman, Faculty Search Committee, Department of Electrical Engineering and Computer Engineering, Iowa State University, Ames, Iowa 50011. Iowa State University is an Equal Opportunity/Affirmative Action Employer.

Lehigh University—Department Chairperson with Endowed Professorship. Nominations and applications are invited for the position of Chairperson and Chandler-Weaver Professor of the Department of Computer Science and Electrical Engineering, College of Engineering and Applied Science. We are seeking candidates with a record of distinction in university teaching and research and a devotion to quality undergraduate and graduate education. The successful candidate must have a demonstrated potential for academic administration and leadership, and have a strong commitment to furthering the research endeavor in the Department and to building a nationally recognized graduate program. The Department offers B.S. and M.S. degrees in Electrical Engineering, Computer Engineering, and Computer Science; and Ph.D. degrees in Electrical Engineering and in Computer Science. It is the largest department in the College of Engineering and Applied Science and awards annually about one third of Lehigh's engineering degrees at the undergraduate and graduate levels. The University is located in eastern Pennsylvania, a short distance from New York City and Philadelphia. The position will be available at the start of the 1992-1993 academic year. Please send application (with at least three references) or nominations addressed to Professor Kenneth K. Tzeng, Search Committee Chairperson, Department of Computer Science and Electrical Engineering, Packard Laboratory #19, Lehigh University, Bethlehem, PA 18015. Lehigh University is an Equal Opportunity/Affirmative Action Employer.

Electrical and Computer Engineering, Faculty Positions -Penn State. Applications are invited for several tenure-track faculty positions in the Department of Electrical and Computer En-

gineering at The Pennsylvania State University. Candidates should have a Ph.D. in Electrical/Computer Engineering or a related discipline, ability to establish a strong research program, and a desire to teach at both the undergraduate and graduate levels. Although candidates in all areas will be considered, the following areas will receive priority consideration: computer engineering (especially software), electromagnetics, space science, electro-optics, electronic materials and power systems. The Department of Electrical and Computer Engineering at Penn State currently has over 50 faculty, 800 junior and senior level students, and 280 graduate students. Funded research is being conducted in many areas, including: Electromagnetics; Electro-optics; Signal Processing; Computer Hardware, Software, and Applications; Power; Electronic Materials; Communications; Control and Robotics. Please send resumes and cover letters, with names, addresses and phone numbers of at least three references, to: Personnel Committee, Department of Electrical and Computer Engineering, Box IEEE, 129 EE East, The Pennsylvania State University, University Park, PA 16802. Applications received by January 31, 1992 will be assured of consideration; however, applications will be considered until the positions are filled. An Affirmative Action/Equal Opportunity Employer. Women and Minorities Encouraged to apply.

Western Michigan University; computer engineering/design. The Department of Electrical Engineering invites applications for two anticipated tenure-track faculty positions, one at the Associate/Assistant Professor level, the other at the Assistant level. Final authorization for these positions is subject to budgetary approval. Preferred applicants must have an earned PhD in Computer Engineering or the equivalent and specialize in computer engineering and design. Responsibilities include graduate and undergraduate teaching, curricular leadership, and research. Senior faculty applicants should demonstrate experience in applied computer engineering design. Western Michigan University is located in Kalamazoo, Michigan and has approximately 26,000 students; it is one of the state's five graduate intensive universities and is designated a Carnegie Doctoral I university. The Department offers two EAC/ABET accredited undergraduate degrees (Computer Systems Engineering and Electrical Engineering) and a growing graduate program. We are looking for experienced computer engineering faculty members who enjoy teaching and would like to participate in building a design-oriented graduate program in computer engineering. Please send a detailed resume, including a statement of citizenship, and names of three references to: Dr. Thomas F. Piatkowski, Chair, Department of Electrical Engineering, Western Michigan University, Kalamazoo, MI 49008-5066 or piatkowski@gw.wmich.edu. Applications will be accepted until the position is filled. Western Michigan University is an affirmative action employer/equal opportunity institution and encourages applications from women and minority candidates.

University of Colorado at Boulder. The Department of Electrical and Computer Engineering invites applications for several tenure-track faculty positions. Areas of particular interest are software and computer engineering, control systems, VLSI/CAD, solid state quantum phenomena device theory, and power (-electronics, -conversion, -systems). Applicants must have a doctoral degree in Electrical Engineering, Computer Engineering, Computer Science, or related fields. Preference will be given to candidates at the Assistant Professor level, but candidates at all levels will be considered. The University of Colorado at Boulder has a strong institutional commitment to the principle of diversity in all areas. In this spirit, we are particularly interested in receiving applications from a broad spectrum of people, including women, members of ethnic minorities and disabled individuals. Applications of these position should be sent to: Prof. William M. Waite, Chairman, Dept. of Electrical and Computer Engineering, University of Colorado, Campus Box 425, Boulder, CO 80309-0425. Application deadline is February 29, 1992.

(Continued on p. 55)

Calendar

(Continued from p. 8)

FEBRUARY

International Workshop on Research Issues on Data Engineering (C); Feb. 2–3; Sheraton Hotel, Tempe, Mission Palms, Ariz.; IEEE Computer Society, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013.

Eighth Semiconductor Thermal Measurement and Management Symposium (CHMT); Feb. 3–5; Pamhlysmith 4 Seasons Hotel, Austin, Texas; Kaveh Azar, AT&T Bell Laboratories, 1600 Osgood St., N. Andover, Mass. 01845; 508-960-6443.

Conference on Optical Fiber Communication–OFC '92 (COM, LEO); Feb. 3–7; San Jose Convention Center, San Jose, Calif.; Susan Evans, IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3896.

Eighth International Conference on Data Engineering (C); Feb. 3–7; Tempe Sheraton, Tempe, Ariz.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1906; 202-371-1013; fax, 202-728-0884.

Sixth International Photovoltaic Science and Engineering Conference (ED); Feb. 10–14; Hotel Taj Palace Intercontinental, New Delhi, India; B.K. Das, PVSEC-6 Conference, National Physical Laboratory, Krishnan Road, New Delhi—110012, India; (91+11) 572 6058; fax, (91+11) 575 2678.

International Conference on Intelligent Control and Instrumentation (Singapore Section); Feb. 18–21; Hilton International, Singapore; R. Devanathan, 200 Jalan Sultan, 11-03 Textile Centre, Singapore 0719; (65) 291 9690; fax, (65) 292 8596.

International Solid State Circuits Conference–ISSCC (Solid State Circuits Council, et al.); Feb. 19–21; San Francisco Hilton Hotel, San Francisco; Diane Suiters, Courtesy Associates Inc., 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-347-5900.

Applied Power Electronics Conference and Exposition (PEL); Feb. 23–27; Westin Hotel, Boston; Melissa Widerkehr, Courtesy Associates, Suite 300, 655 15th St., N.W., Washington, D.C. 20005; 202-639-4990; fax, 202-347-6109.

Compcon Spring '92 (C); Feb. 24–28; Cathedral Hill Hotel, San Francisco; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

MARCH

First International Fuzzy Systems Conference (COM, IE, NN); March 8–12; Town & Country Hotel, San Diego, Calif.; Nomi Feldman, Meeting Management, 5665 Oberlin Dr., Suite 110, San Diego, Calif. 92121; 619-453-6222.

Southcon '92 (Region 3); March 10–12; Orange Country Convention/Civic Center, Orlando, Fla.; Electronic Conventions Management, 8110 Airport Blvd., Los Angeles, Calif. 90045; 213-215-3976 or 800-877-2668.

Fourth International Conference on Microelectronic Test Structures (ED); March 17–19; Catamaran Resort Hotel, San Diego, Calif.; Michael W. Cresswell, National Institute of Standards and Technology, B360 Technology, Gaithersburg, Md. 20899; 301-975-2072; fax, 301-975-2128.

† Check author entry for subsequent corrections/comments

+ Check author entry for coauthors

† Check author entry for subsequent corrections/comments

+ Check author entry for coauthors

† Check author entry for subsequent corrections/comments

News Index

CLASSIFIED EMPLOYMENT OPPORTUNITIES

Academic Positions Open

McGill University's Computer Systems and Circuits Laboratory has an opening for Post-Doctoral Fellow to carry our research in the areas of analog IC design and mixed-signal ASIC testing. Candidates should have extensive research experience in one of the two areas: analog IC circuit design or analog testing. The initial appointment is for one year and can be renewed for two subsequent years. The annual salary is CND $29,000. Applicants should send their resume with names and addresses of three references to: Prof. Gordon Roberts, Department of Electrical Engineering, McGill University, 3480 University Street, Montreal, Quebec, Canada H3A 2A7. Fax (514) 398-4470.

Research Associate to apply expert system and decision making analysis to electrical power systems, which includes designing decision making systems for high impedance fault detection, applying learning algorithms into adaptive relaying for power distribution protection, and artificial intelligence and expert system programming in microcomputer system environments. Design and test real-time expert system applicable into power system diagnosis with artificial intelligence reasoning methodology, and with programming by codes for Fortran, C, Clips, and Lisps. Neural Network approach including adaptive filtering method and back propagation, method into a learning algorithm improvement. Revision of adaptive filtering methods into multiple uncertain information environment such as high impedance fault detection and discrimination from other normal switching events. Salary $1,854 per month, 40 hours per week. Requires Ph.D. in Electrical Engineering, and 2 years related experience in power distribution system control or monitoring with computer. Apply at the Texas Employment Commission, Bryan, Texas, or send resume to the Texas Employment Commission, TEC Building, Austin, Texas 78778, J.O. #6521439. Ad paid by an Equal Opportunity Employer.

Electrical Engineering: Tenure-track position available in fall 1992. Ph.D. desired; MS with significant industrial experience considered. Specialty in digital electronics preferred. Must be interested in a strong undergraduate teaching environment. The successful candidate will assist in the development of curriculum and laboratories in a relatively new BSE program having options in electrical and mechanical engineering. Messiah College seeks candidates committed to an evangelical expression of the Christian faith. Send letter of inquiry and resume to Dr. James Scroggin, Chair, Department of Engineering, Messiah College, Grantham, PA 17027. Minorities and women strongly encouraged to apply. AA/EOE.

The Johns Hopkins University, Department of Electrical and Computer Engineering, invites applications for tenure-track faculty positions at the assistant or associate professor level in the areas of computer engineering; solid state and quantum electronics; and signal and image processing. Candidates for associate professor appointments are expected to have significant research records. Candidates for assistant professor appointments are expected to show strong research potential. Applicants should send resumes, including names of at least three references, to Search Committee, Department of Electrical and Computer Engineering, The Johns Hopkins University, Baltimore MD 21218-2868. The Johns Hopkins University is an equal opportunity/affirmative action employer.

Senior Faculty Position. Theoretical or Experimental Condensed Matter, The University of North Carolina at Charlotte. The Department of Physics at UNC Charlotte is seeking an outstanding condensed matter physicist to complement its expanding applied physics program which emphasizes research in applied optics. Candidates must have an excellent research record, show potential for leading a research program in his/her field, and have experience appropriate for appointment at the rank of professor. Researchers in the areas of Materials Science, Solid State physics and Optoelectronics are encouraged to apply. Salary will be commensurate with qualification and experience. The department has research capabilities in the areas of optical image processing, pattern recognition, holography, fiber optics, quantum optics, non-linear optics and radiation damage in solids. Some of the research facilities are housed in the newly built university Applied Research Center. UNC Charlotte is experiencing a steady growth and currently enrolls more than 15,000 students. Applicants should send a letter explaining their interest in the position, a resume, and the names, addresses, and phone numbers of a least three references to Dr. T.W. Mayes, Chair, Search Committee, Department of Physics, UNC at Charlotte, Charlotte, NC 28223. (Telephone 704-547-4516). Review of applications is expected to begin January 15, 1992 and continue until the position is filled. UNC Charlotte is an Equal Opportunity/Affirmative Action Employer.

Director, Manufacturing Engineering University of Michigan-Dearborn. Applications and nominations are invited for the position of the Director, Manufacturing Engineering Program at the University of Michigan-Dearborn. The Manufacturing Engineering Program is an interdisciplinary activity offering a master's degree in Manufacturing Systems Engineering and conducting innovative research with emphasis on product quality and productivity. Specific research interests currently include topics in machine vision, machine diagnostics, precision machining, casting, plastics and composites manufacturing. Located in the center of the automotive industry, it enjoys close interaction and support from local industry. Candidates for the position should have an earned doctorate degree in engineering or equivalent research experience, and, a demonstrated ability for research development and management. Some experience in industry and/or government is highly preferred. Besides directing the Manufacturing Engineering Program, the Director will have responsibility for generating and administering research funds, advising and working closely with the faculty on their research activities, and teaching. Responsibilities will also include directing the Manufacturing Systems Engineering Laboratory which is a 10,000 sq. ft. interdisciplinary research facility, and, administering state funded Research Excellence and Economic Development Program. The Director will be expected to provide leadership and vision in the continuing growth of the program and strengthening its ties with industry and government agencies. He/she will report directly to the Dean. A curriculum vitae and names of three references should be sent to Professor P.K. Mallick, Chair, Director Search Committee, Department of Mechanical Engineering, The University of Michigan-Dearborn, 4901 Evergreen Rd., Dearborn, MI 48128. Review of applications and nominations will start on January 15, 1992; however, they will be accepted until the position is filled. The University of Michigan-Dearborn is an equal Opportunity/Affirmative Action Employer and encourages women and minorities to apply.

Research Assistant Professor. We are seeking a qualified PhD computer scientist or imaging specialist to design and lead the development and implementation of an integrated computerized imaging network for stereotaxic neurosurgical procedures. The stereotaxic imaging system will integrate CT, MRI, as well as conventional and digital subtraction angiography and will include surgical planning programs for the Gamma Knife Radiosurgery device. Incumbent will develop or apply necessary image processing and analysis paradigms for the imaging network, and will supervise a computer engineer responsible for network development and implementation. PhD in Computer Science or Biomedical Engineering with a demonstrated high level of expert knowledge in computer/stereotaxic image processing and analysis as evidenced by significant publications and/or work experience. Appointment will be at the Research Assistant Professor level. Record of ability to organize and lead team assembled to develop and implement network a must. Applicants are asked to send curriculum vitae and names of three references to G. Rees Cosgrove, MD, Department of Neurological Surgery, Box 212, University of Virginia Health Sciences Center, Charlottesville, Virginia 22908. Equal Opportunity/Affirmative Action Employer.

University of Kansas-Electrical and Computer Engineering. A tenure-track faculty opening at the Full or Associate Professor level may be available beginning August 1992 or as negotiated. Rank and salary will be commensurate with qualifications. A doctorate is required. Applicants are sought with teaching and research interest in all areas of computer engineering. New faculty will be expected to perform teaching and curriculum development, to conduct research, and to provide leadership in the area of computer engineering. Preference will be given to applicants with a strong research record and/or industry experience, and whose research interests are consistent with ongoing activities within the Department, especially in software engineering, VLSI design, computer architectures, and artificial intelligence. Review of applications will begin on December 15, 1991 and continue until the position is filled. Send resumes to Dr. Costas Tsatsoulis, Chairman of the Faculty Search Committee, Department of Electrical and Computer Engineering, The University of Kansas, Lawrence, Kansas 66045. Telephone: (913) 864-7749. E-mail: tsatsoul%turing@kuhub.cc.ukans.edu. The University of Kansas is an equal opportunity/affirmative action employer.

The University of Cincinnati. The NASA Space Engineering Research Center and the Department of Electrical and Computer Engineering invite applications for new tenure-track faculty positions at the Assistant/Associate Professor levels starting January 1992. The primary areas of interest are solid state electronics with an emphasis on microelectronics-based sensors, micromechanical structures, microstructures, chemical or RIE micromachining, analog and digital electronics circuit design for smart sensing, electronic instrumentation and non-intrusive diagnostics using microsensors for space engineering. The Department offers B.S., M.S., and Ph.D. programs in Electrical and Computer Engineering. The Department has 30 full-time faculty, 160 full-time graduate students, 400 undergraduate students, 2 research centers, and 20 full-time staff members, and graduates approximately 35 M.S. and 15 Ph.D.'s per year. Externally funded research is currently at $4.0M per year and growing. The University is supportive of the Department in providing an environment conducive to the establishment of an academic and professional career. The Space Engineering Research Center is one of nine national research centers sponsored by NASA. It currently supports multi-disciplinary research and educational programs involving faculty and students in the College of Engineering. The successful candidate will hold a regular full-time faculty rank in the Department of Electrical and Computer Engineering with a joint appointment at the NASA Space Engineering Center. He/she is expected to play a leading role in the development of a collaborative research and educational program between the Space Research Center and the Department in microsensors and instrumentation. All candidates should have a strong commitment to excellence in research and teaching and an earned Ph.D. in electrical engineering. Please send curriculum vitae to: Dr. Vik J. Kapoor, Head, Electrical and Computer Engineering Department, University of Cincinnati, Cincinnati, Ohio 45221-0030. E-mail vkapoor@uceng.uc.edu. The University of Cincinnati is an Affirmative Action/Equal Opportunity employer and encourages and welcomes applications from women and minorities.

Computer Engineering Faculty Position, Washington State University—Spokane. The School of Electrical Engineering and Computer Science at Washington State University invites applicants for a full-time, tenure track faculty position at the assistant/associate professor rank. Responsibilities include graduate instruction—both electrical engineering and computer science courses in the individual's area of expertise. Also, the individual will be ex-

pected to develop and operate a research program. Candidates for the assistant professor level should demonstrate a strong potential for developing a significant research program. Candidates for higher levels must have a proven record of accomplishment. Industry experience or experience with industry relations is highly desired. An NSF Industry/University Cooperative Research Center in analog-digital integrated circuits exists, which provides many opportunities for collaborative research in integrated circuit design, algorithms, and design methodology. The Spokane program has close ties with the main campus in Pullman. Facilities include engineering workstations, networked computers, and modern equipment in the various laboratories. Close association with the Spokane Intercollegiate Research and Technology Institute is anticipated. The latter is a consortium of five institutions of higher education, including WSU, committed to applied research and economic development in the Spokane area. Washington State University is a multicampus system with a single faculty, geographically diverse. This position is located at WSU Spokane and has reporting lines to the Director of the School of Electrical Engineering and Computer Science and the Dean of the College of Engineering and Architecture. Spokane is a major service center of eastern Washington, northern Idaho, western Montana, and the southern parts of the Canadian Provinces of British Columbia and Alberta. The metropolitan area includes a population of 375,000 with social and cultural amenities not often found in a community of its size. Send resumes with names and addresses of at least three references to: Dr. Yacov Shamash, Director, School of Electrical Engineering and Computer Science, Washington State University, Pullman, WA 99164-2752. WSU is an EO/AA educator and employer. Women and minorities are encouraged to apply.

Southern Methodist University, Computer Science and Engineering. The Department of Computer Science and Engineering (CSE) invites applications for a senior faculty position in Computer Engineering at the Associate or Full Professor level. Applicants must have a Ph.D. in Computer Engineering, Computer Science, or a related discipline. Candidates should have an outstanding funding and research record in the area of Computer Engineering with a strong commitment to teaching. It is anticipated that the position will be filled by August, 1992. SMU is a private university with approximately 8,000 students. The Department of Computer Science and Engineering is in the School of Engineering and Applied Science, where a close working relationship exists with the Departments of Electrical Engineering and Mechanical Engineering. The CSE Department presents a balanced program of research and education at all levels and has been offering Ph.D. degrees since 1970. The Department has extensive contacts with computer-related and engineering-oriented industrial firms that distinguish Dallas as one of the top centers for high technology. Applicants should send a complete resume, including the names of at least three references to: Professor Margaret H. Eich, Chair, Faculty Search Committee, Department of Computer Science and Engineering, Southern Methodist University, Dallas, Texas 75275-0122. SMU is an equal opportunity/affirmative action, Title IX employer. Applications from women and minorities are particularly encouraged. Applications will be accepted until February 1, 1992.

Case Institute of Technology, NORD Professorship in Computer Engineering and Science. The Department of Computer Engineering and Science at Case Institute of Technology is seeking a nationally recognized scholar and researcher to fill the NORD Professorship. This position was recently established by the donation of over one and a half million dollars, which will provide outstanding professional opportunities and a highly competitive salary, together with additional funds for travel, graduate student support and equipment. The qualifications include a Ph.D. in computer science, computer engineering or closely allied fields, and an ability to establish and develop external support for a nationally recognized research program in computer science/computer engineering. We encourage applicants in all research areas, but our current research thrusts are in computer architecture and VLSI design, software engineering and systems, database systems, and artificial intelligence and logic programming. CWRU is a private university with a total enrollment of 8,400, of which 5,100 are graduate and professional students. The Engineering School of Case Institute of Technology is among the top ten engineering schools in terms of research funding per faculty member and undergraduate student quality. The University campus is the hub of the pleasant area known as University Circle, an incorporation with neighboring cultural centers and museums, about five miles from downtown Cleveland. The Department of Computer Engineering and Science has 13 faculty positions, and a graduate student body of 140 students, 60 of which are in the Ph.D. program. Departmental facilities are based upon an ethernet local area network, connected to INTERNET, which supports a UNIX operating system and about 40 SUN and other workstations. In addition, faculty and students participating in the Center for Automation and Intelligent Systems Research have access to the Center's computing facilities. Applicants should submit their curriculum vitae and names of at least five references to: Lee J. White, Chairman, Department of Computer Engineering and Science, Case Western Reserve University, Cleveland, Ohio 44106: INTERNET: leew@alpha.ces.cwru.edu; applicants may wish to provide at most three reprints of their most important publications. An equal employment and affirmative action employer.

University of Alabama in Huntsville—Graduate Assistantships in Electrical and Computer Engineering. We are seeking to appoint US citizens with outstanding credentials who intend to pursue the doctorate in optical engineering, communications, VLSI design, computer engineering, signal and image processing, controls, and electromagnetics. In addition to our undergraduate and graduate degrees in electrical and computer engineering, we offer the baccalaureate in optical engineering and are preparing to introduce an interdisciplinary doctorate in optical science and engineering. The department will grow from the current faculty complement of 26 to 30 within the next three years. We currently enroll 650 undergraduates and 210 graduate students. We intend to double our full-time graduate student population to 80 by 1995. UAH has attained national prominence in research, ranking 113 in federal funding, with total extramural support amounting to $30,000,000 per year. The university benefits from the high technology environment in Huntsville, which employs 20,000 scientists and engineers. Among the major organizations are the US Army Missile Command, the NASA Marshall Space Flight Center, Intergraph, SCI, BDM, and Teledyne-Brown Engineering. The new Optics Building houses optics-related research facilities and personnel, including the UAH Center for Applied Optics. Computer resources include a CRAY X-MP/24, a component of the Alabama Supercomputer Network. Major departmental laboratories include Digital Signal Processing, Communications and Control; VLSI Design; and Opto-electronics. Assistantship stipends range from $10,000 to $20,000 per calendar year and all include tuition remission. We encourage those from groups underrepresented in engineering to apply. Send resume and transcript with the names of three faculty references from accredited American universities to Professor Stephen T. Kowel, Chairman, ECE Department, University of Alabama in Huntsville, Huntsville, AL 35899. UAH is an Affirmative Action/Equal Opportunity Employer.

Rice University Department of Electrical and Computer Engineering invites applications for faculty positions in the areas of robotics, signal processing, and computer systems. Applicants in the area of robotics should be interested in space or undersea applications and be able to lead a robotics laboratory. Applicants in signal processing should have a background in basic signal and systems with interests in image and multidimensional processing. Applicants in the computer systems area should have interests in the general areas of computer architecture, operating systems, and parallel computing. Outstanding applicants working in related areas will also be considered. Rice University is a small, private university with a strong commitment to excellence in both teaching and research. Rice is located in Houston, Texas, a city with affordable housing and excellent fine arts. Applicants should submit their resume, a summary of their research accomplishments, and the names of at least three references to the Chairman of the Department of Electrical and Computer Engineering, Rice University, P.O. Box 1892, Houston, TX 77251-1892. Rice University is an equal opportunity/affirmative action employer.

Dean, G.W.C. Whiting School of Engineering, The Johns Hopkins University, Baltimore, Maryland. The Johns Hopkins University is seeking applications and nominations for the position of Dean of the G.W.C. Whiting School of Engineering. The School has a full-time faculty of 90, an undergraduate student population of 760, a graduate student population of 385, and a large part-time Masters degree program with 285 part-time faculty and 2500 part-time students. The School covers a wide range of fields and specialties in the following departments as well as in several interdepartmental degree programs. Biomedical Engineering; Chemical Engineering; Civil Engineering; Computer Science; Electrical & Computer Engineering; Geography & Environmental Engineering; Materials Science & Engineering; Mathematical Sciences; Mechanical Engineering. The Dean has responsibility for and authority over the School's programs and budget within the context of a highly decentralized university. The University seeks an individual of distinguished accomplishment to work with the faculty and the university in leading a School with a tradition of excellence in research, teaching, and service. Candidates should have demonstrated leadership skills in administration, fund raising and strategic planning as well as the ability to work constructively and creatively in collaborative relationships with the School of Arts and Sciences, School of Medicine, and the Applied Physics Laboratory. Nominations and applications should be sent to: Dr. Joseph Cooper, Provost, Chair, Search Committee, Eng'g, The Johns Hopkins University, 34th and Charles Sts., Garland Hall 265, Baltimore, MD 21218. The Search Committee will begin reviewing nominations and applications on November 15, 1991. The university expects to fill this position before July 1992. The Johns Hopkins University is an Equal Opportunity/Affirmative Action Employer and encourages applications from women and minorities.

The University of Detroit Mercy. The Department of Electrical Engineering invites applications for a tenure track assistant professorship. Duties include teaching undergraduate and graduate courses in electrical engineering and developing funded research programs. Earned doctorate in electrical engineering with specialization in computer hardware and digital systems and excellent communication skills are required. The University of Detroit Mercy is a new university created in 1990 by the consolidation of two outstanding leaders in private education, the University of Detroit and Mercy College of Detroit. The resulting university is the largest private university in Michigan. The College of Engineering and Science is widely known for its teaching and research partnerships with industry. Applications with complete resumes including full academic transcripts and names of at least three references should be sent to Prof. D.L. Sengupta, Chairperson, Electrical Engineering Department, University of Detroit Mercy, P.O. Box 19900, Detroit, MI 48219-3599. Equal Opportunity/Affirmative Action Employer.

University of Arizona. The University of Arizona Electrical and Computer Engineering Department invites applications for one or more tenure track faculty appointments for the 1992-93 academic year. Preference will be given to applicants at the Assistant Professor level, but exceptional candidates at higher levels may also

be considered. In addition to an earned doctorate and a commitment to effective teaching at both the undergraduate and graduate level, it is essential that candidates have outstanding research achievement and/or potential and the commitment and ability to establish an externally sponsored research program. Technical areas of particular interest for 1992-93 recruiting are: (1) computer engineering emphasizing VLSI design and test and/or interconnection networks for parallel and distributed processing systems; (2) communications systems: (3) and microelectronics emphasizing microelectronics manufacturing and/or semiconductor processing science. Applicants should send a resume, a statement of teaching and research interests, and a list of three references to: Prof. K.F. Galloway, Department Head, Electrical and Computer Engineering Department, University of Arizona, Tucson, AZ 85721. Applications will be reviewed starting January 15, 1992 and will be received until open positions are filled. The University of Arizona is an Equal Opportunity/Affirmative Action Employer and specifically invites women and minorities to apply.

University of Alabama in Huntsville, Department of Electrical and Computer Engineering. Five faculty positions—rank and specialty areas open. We seek U.S. citizens or permanent residents with excellent academic credentials holding the Ph.D. in electrical or computer engineering, or in cognate fields. Junior appointees should have outstanding potential as teachers and researchers; senior appointees are also expected to possess a record of substantial research support and productivity. We are particularly interested in filling positions in opto-electronics, communications, radar systems, signal processing, electronics and computer engineering. The department, with 26 faculty members, currently enrolls 630 undergraduates and over 250 graduate students. The department offers baccalaureate degrees in electrical engineering, computer engineering, and optical engineering, and masters and doctoral degrees in both electrical and computer engineering. The new Optics Building houses optics-related research facilities and personnel, including the UAH Center for Applied Optics. Computer resources include a CRAY X-MP/24, a component of the Alabama Supercomputer Network. Major departmental laboratories include Digital Signal Processing, Communications and Control; VLSI Design; and Optoelectronics. Huntsville is a high technology community, with many federal and corporate opportunities for collaboration, support and consulting. It is situated on the Tennessee River, in the foothills of the Appalachian Mountains. Climate is temperate, and opportunities for recreation as well as cultural activities abound. Salary and benefits are highly competitive, while housing is very affordable. Please send curriculum vitae with the names of three references to Professor Stephen T. Kowel, Chairman, Department of Electrical and Computer Engineering, University of Alabama in Huntsville, Huntsville, Alabama 35899. UAH is an Affirmative Action/Equal Opportunity Employer.

University of Colorado at Denver. The Department of Computer Science and Engineering invites applications for a tenure-track faculty position, beginning August 1992. Though expertise in any recognized area of computer science will be considered, we are especially interested in applicants with research interests in software engineering, parallel-distributed computation, databases, and programming languages-compilers. An earned doctorate in computer science or a related field, evident research potential, and teaching ability at both the undergraduate and graduate levels are required. An established research record is expected at appointment levels above initial assistant professor. Rank and salary will be commensurate with experience. Send vitae and names of at least three professional references by 21 February, 1992 to: Professor John Clark, Chair, Faculty Search Committee, University of Colorado at Denver, Department of Computer Science & Engineering, Campus Box 110, P.O. Box 173364, Denver, CO 80217-3364. The University of Colorado at Denver is strongly committed to the diversity of its faculty and staff, invites applications from a broad spectrum of people, and particularly encourages applications from women and members of ethnic minority groups.

Montana State University seeks qualified candidates at the Assistant Professor level in two areas: 1) logic circuits and microprocessor applications with specialization in digital signal processing or VLSI design; and 2) electronics with specialization in power electronics. Applicants must hold an earned Ph.D. degree in Electrical Engineering or closely related field, have specialization in one of the two areas listed above, and have demonstrated potential for teaching at the undergraduate and graduate levels and for developing an independent research program. Industrial experience is desirable. The Electrical Engineering Department offers programs leading to BS, MS and Ph.D. degrees. Curriculum vitae, a list of 3 references and a statement about teaching philosophy and research interests should be addressed to: Dr. Donald A. Pierre, Head, Electrical Engineering Search Committee, Department of Electrical Engineering, Montana State University, Bozeman, MT 59717-0378. Applications must be postmarked by February 15, 1992. Montana State University is an AA/EO Employer, and preference is given to eligible veterans.

University of California at Berkeley Faculty Positions in Simulation and Visualization, Electronic and Optoelectronic Devices and Technology, and Low-Temperature Electronics, beginning in Fall Semester 1992, pending budgetary approval. The Department of Electrical Engineering and Computer Sciences at the University of California at Berkeley is currently seeking outstanding faculty candidates with research in the general areas of: (i) Simulation and Visualization. Areas of interest include the use of computers to simulate complex phenomena, devices, and systems, and to the presentation of these calculations in visual form to promote understanding. The candidate must emphasize the use of simulation and visualization in at least one of the following application areas: a. the reconstruction of multidimensional configurations (3D or higher) from lower dimensional data as in tomography, NMR and NRI imaging, and in seismic data b. the analysis, understanding, and design of complex control or communication systems c. the analysis and design of electronic or mechatronic devices d. the modeling of complex physical phenomena, including plasmas, semiconductor processing equipment and semiconductor devices. The candidate should be able to teach basic courses in systems, communications and control. Appointment will be made only at the Assistant Professor level in a tenure-track position. (ii) Electronic and Optoelectronic Devices and Technology. Areas of interest include electronic/optoelectronic devices based on nanostructures and/or ultrafast phenomena. Candidates should have a strong record of research and are expected, along with other members of the faculty in this and other departments (material science and physics) as well as scientists at Lawrence Berkeley Laboratory, to provide leadership in this field of research. Although technology and fabrication aspects are considered an essential part of nanostructure/high speed device research, preference will be given to research in the actual creation of novel devices/new functions and device physics studies. The potential to initiate collaborative efforts involving advanced facilities, such as Advanced Light Source (Synchrotron radiation) at Lawrence Berkeley Laboratory, will be positively (although by no means exclusively) considered. The candidate should be able to teach basic courses in electronic devices and/or optoelectronics. It is expected that the appointment will be made at a senior, tenured level, although applications will also be considered for a junior level appointment. (iii) Superconductive Electronics. Candidates might have interests in superconducting digital circuit design and/or device and fabrication technology for low and high-temperature superconductors. Candidates will be expected to teach undergraduate and graduate courses in semiconducting or superconducting devices, technology, and/or circuits. The appointment will be made at the Assistant Professor level only in a tenure-track position. Applicants must have a doctoral degree or comparable academic and industrial experience. Interested persons should apply as soon as possible and by February 28, 1992 to insure full consideration, to the Chairman, at the address listed below, including a resume, copies of publications, a statement of interest, and names and addresses of references. Professor Paul Gray, Chairman, Department of Electrical Engineering and Computer Sciences, University of California, Berkeley, California 94720. Telephone (510) 642-0253. The University of California is an Equal Opportunity, Affirmative Action Employer.

Two Tenure-Track Faculty Positions at the Assistant Professor Level are available within the newly formed Division of Medical Imaging Research in the Radiology Department of the Indiana University Medical Center. One imaging scientist with a background in lasers, optics and high speed detectors; and, a second imaging scientist with a background in x-ray imaging and/or radiation physics are sought. Joint appointments in Electrical Engineering or Biophysics may be considered. A Ph.D. degree in a physical science or engineering and a minimum of two years postdoctoral experience is required. The successful applicant will be expected to compete successfully for extramural research support and to teach courses at the graduate level. Applicants should send current resumes and the names of three professional references to: Robert A. Kruger, Ph.D., Indiana University Medical Center, CL 112, 541 Clinical Drive, Indianapolis, IN 46202-5111. Indiana University is an Equal Opportunity/Affirmative Action Employer.

SUNY Stony Brook. The Department of Electrical Engineering, SUNY at Stony Brook, invites applications for anticipated openings for all professor ranks. These positions will be tenure track with salary negotiable. The Department has undergraduate and graduate programs and extensive research activities. The areas of prime interest are computer engineering, digital systems, machine vision, VLSI design, and robotics. The Department has extensive computing facilities. Applicants in other areas will be considered. The Department has close relations with high-technology industry. Stony Brook combines the attraction of a semi-rural location with proximity to the resources of the New York City area. Please submit resume to: Prof. Kenneth L. Short, Chairman, Department of Electrical Engineering, SUNY at Stony Brook, Long Island, New York 11794-2350. SUNY at Stony Brook is an equal opportunity/affirmative action employer. AK88

Electrical Engineering: The Department of Electrical Engineering at Memphis State University is now accepting applications for tenure-track faculty positions. Preference will be given to applicants for the Assistant or Associate Professor level. Applicants with research specializations in computer engineering, biomedical engineering, or electro-optics are preferred. Candidates should be available for employment by August 20, 1992. Research experience and potential for securing funded research will be important considerations in candidate selection. An earned doctorate in electrical engineering or related area is required. Interested applicants should send resumes with names, addresses, and telephone numbers of three references to: Dr. Carl E. Halford, Department of Electrical Engineering, Memphis State University, Memphis, TN 38152. Closing date for applications is January 31, 1992, with initial screening to begin at that time. However, if needed, applications will be reviewed until positions are filled. Equal opportunity, affirmative action employer. Successful candidates must meet Immigration Reform Act criteria.

Faculty Position: The Division of Engineering at The University of Texas at San Antonio invites applications for a tenure-track Assistant Professor position in Electrical Engineering. Ph.D. degree required. Successful candidates are expected to participate in both undergraduate and graduate teaching, and in research activities. Applicants in all areas of electrical engineering are invited to apply, but the following areas are of special interest: computer engineering with emphasis on distributed and parallel processing and fault tolerant computing; digital signal processing; telecommunications; solid state devices; and VLSI. Salary commen-

surate with qualifications and experience. UTSA is a comprehensive metropolitan university located on the edge of the Texas Hill Country. San Antonio combines a rich cultural heritage with a modern focus on education, research, and technology. Send resume and names, addresses, and phone numbers of four references by January 31, 1992 to: Chair, Electrical Engineering Search Committee, Division of Engineering, The University of Texas at San Antonio, San Antonio, Texas 78249-0665. UTSA is an Equal Opportunity/Affirmative Action Employer. Women and minorities are encouraged to apply.

The Department of Electrical Engineering of Arizona State University is seeking a senior faculty member who will play a leading role in the future development of the Nuclear Engineering Science Program at Arizona State University. The successful applicant must have an earned doctoral degree with considerable research experience in a combination of Nuclear and Electrical Engineering. The successful applicant is expected to excel in teaching, at both the undergraduate and graduate levels, and to support activities in either the Electric Power Research Laboratory and/or the Center for Systems Science and Engineering. Preferred areas of specialization include reactor controls, computational reactor analysis, reactor safety, materials damage and instrumentation. Depending upon the background and experience of the successful applicant, there is potential for contract involvement with nearby Palo Verde, the largest Nuclear Generating Station in the world. Academic rank will be commensurate with the candidate's background and experience. Please send applications to Dr. David K. Ferry, Chairman, Department of Electrical Engineering, Arizona State University, Tempe, AZ 85287-5706, Attention: Faculty Search Committee. The first deadline is January 6, 1992, or the 6th of each month until the position is filled. Arizona State University is an equal opportunity, affirmative action employer. Women and minorities are encouraged to apply.

Faculty Position, Physics. GMI Engineering & Management Institute invites applications for a tenure-track position in physics at the level of assistant professor. Outstanding candidates may be considered for appointment at the associate professor rank. The successful candidate must hold a Ph.D. in physics or related discipline and show evidence of outstanding ability to teach physics at all undergraduate levels, the capability to conduct research in an undergraduate environment, and the versatility to interact with colleagues in a multidisciplinary environment. The Science and Mathematics Department offers a Bachelor of Science degree in Applied Mathematics as well as minors in Applied Chemistry, Applied Mathematics, Applied Optics, and Computer Science. The Physics Division is seeking to strengthen its capability in materials science, lasers, optics, with the intent to offer a degree program in applied physics. GMI operates on a five-year fully cooperative plan of undergraduate education. The college also offers bachelor of science degrees in mechanical, industrial, electrical, and manufacturing systems engineering, and management. Masters degrees are offered in manufacturing management and engineering. GMI strongly supports collaborative research and consulting between faculty and industrial partners. Please send resume, statement of research objectives, and arrange to have three letters of reference sent to: Dr. Richard Bolander, Chair, GMI Physics Faculty Search Committee, Science and Mathematics Department, GMI Engineering & Management Institute, 1700 West Third Avenue, Flint, MI 48504-4898. Applications will be accepted until February 20, 1992. The appointment commences September 15, 1992. Minorities and women are encouraged to apply. GMI is an Affirmative Action/Equal Opportunity Employer.

University of Idaho—Department of Electrical Engineering invites applications for tenure-track positions at the assistant professor level with a specialty in power systems or analog electronics. If suitable candidates in these specialties are not identified, candidates in computer engineering, digital systems, control systems, or electromagnetics may be considered. Duties include teaching at the graduate and undergraduate levels, research in the specialty area, and contributing to the academic program in the Department. Qualifications include an earned PhD in electrical engineering or closely related field, excellent teaching ability, potential for a strong research program, and USA citizenship or permanent residency. The Department offers the BS, MS, and PhD in electrical engineering and the BS and MS in computer engineering. The University of Idaho has statewide responsibility for engineering education, is a land-grant university with about 9,000 students, and is located in northern Idaho approximately 10 miles from Washington State University. Research activity includes the Microelectronics Research Center (MRC), specializing in VLSI design; the MRC receives NASA support as one of nine original Space Engineering Research Centers. Search and selection procedures will be closed when a sufficient number of qualified applicants has been identified, but not earlier than January 20, 1992. Send letter, resume, and names of three references to Dr. James N. Peterson, Department of Electrical Engineering, University of Idaho, Moscow, Idaho 83843-4199. The University of Idaho is an EO/AA employer.

University of Illinois at Urbana-Champaign: The Department of General Engineering invites applications for a tenure-track faculty position in the general areas of robotics and control. Areas of particular interest in control include multivariable and decentralized systems, discrete event dynamical systems, design of control scheduling systems (including expert control, fuzzy controllers, AI-based and knowledge-based control), nonlinear system theory and design of nonlinear and adaptive controls, and neural networks for modeling and control. Areas of particular interest in robotics include robot modeling, design and computer animation, sensor-based control and sensor fusion, teleoperators, biomedical applications, and automation and manufacturing systems. However, candidates with strong credentials in all areas of robotics and control will be considered. The appointment will normally be made at the assistant professor level, but a senior level appointment with tenure is also possible for a person of recognized national and international stature. An earned Ph.D. degree in engineering is required. The candidate must be committed to teaching at the undergraduate and graduate levels as well as developing a high quality, externally supported program of research. Salary is commensurate with education and experience. The starting date is August 21, 1992. The Department has 23 faculty, 650 students at the undergraduate and graduate levels, and research programs in engineering design, robotics and control, design and manufacturing systems, artificial intelligence/operations research, biomechanics, and nondestructive evaluation. Applications, including a letter of interest, a curriculum vitae, complete publication list, dissertation abstract, undergraduate and graduate transcripts and the names of three references should be sent to: Dr. Thomas F. Conry, Head, Department of General Engineering, University of Illinois at Urbana-Champaign, 104 South Mathews Avenue, Urbana, Illinois 61801; (217-333-2730). In order to ensure full consideration, applications must be received by February 20, 1992, though applications will be considered until the position is filled. Some interviews may be conducted before the deadline, but no finalists will be established before the deadline. The University of Illinois is an Affirmative Action, Equal Opportunity Employer.

Lafayette College: Tenure-track Assistant Professor position beginning August 1992, in the Electrical Engineering Department. Disciplines of particular interest are Power Systems and Energy Conversion. Requires PhD in Electrical Engineering and a strong commitment to undergraduate education. Lafayette College enrolls 2,000 students and is an independent, highly selective undergraduate institution having EAC/ABET accredited programs in four engineering disciplines. Women and minorities are encouraged to apply. Send resume, with three references and statement of teaching and research interests, to Dr. William Hornfeck, Electrical Engineering Department, Lafayette College, Easton, PA 18042-1775. Lafayette is committed to equal opportunity through affirmative action.

Electrical Engineering Technology. Search reopened for Assistant Professor or Associate Professor starting September 1, 1992. Minimum requirements: B.S. and M.S. in EET, EE or related field and a minimum of three years of relevant engineering experience. Professional registration will be required for tenure. Teaching experience desirable. Expected to teach TAC/ABET accredited Associate and Baccalaureate courses in one or more of the following areas: (1) Industrial controls and power electronics; (2) Linear electronics and communications; and (3) Power systems and machinery. Position is open until filled. Rank and salary will be commensurate with qualifications. Send resume with names and addresses of three references to: John J. McDonough, Director, School of Engineering Technology, 221 East Annex, University of Maine, Orono, ME 04469. The University of Maine is an Equal Opportunity/Affirmative Action Employer.

Assistant Professor, Telecommunications. SUNY Institute of Technology at Utica/Rome. Duties include teaching and advising undergraduates, with opportunity to conduct research. May also include teaching graduate level courses. Qualifications: Must possess strong background in both voice and data communications, including a "hands-on" knowledge of various telecommunications equipment including T-1 multiplexors, network testing and diagnostic equipment, telephone switching and transmission systems, fiber-optics and wiring/cabling systems. Previous teaching experience and Master's degree in applicable field is required, Ph.D. is preferred. Must have direct industry experience in addition to academic accomplishments. Review of applicants will begin January 1, 1992, and continue until the position is filled. Selected candidate will begin September 1992. Send letter of application and resume to: Mr. Anthony Panebianco, Director of Personnel/AA, SUNY Institute of Technology at Utica/Rome, Drawer 91037, P.O. Box 3050, Utica, NY 13504-3050. An Equal Opportunity/Affirmative Action Employer.

Associate Chairperson, Department of Electrical and Computer Engineering, Florida International University, A State University of Florida at Miami. Nominations and applications are invited for the 12-month/year position of Associate Chairperson (Associate/Professor rank) of the Department of Electrical & Computer Engineering with duties mainly in computer engineering. The department of Electrical and Computer Engineering is the largest department in the College and offers B.S. (accredited), M.S., and Ph.D. degrees in electrical and computer engineering. Qualifications: Earned doctorate with a strong record of funded research, preferably from government agencies, desire to direct and assist faculty in obtaining funded research and experience in computer related areas. Also assist Chairperson in day-to-day departmental administration activities. Rank and salary are commensurate with qualifications and experience. Applications and Dates: All applications received prior to January 23, 1992, will receive full consideration. The positions will be available starying August, 1992. U.S citizens or lawfully authorized alien workers should send a letter addressing the qualifications above, a resume, and three references (names) to: Dr. Wunnava V. Subbarao, Chair, Search and Screen Committee, Department of Electrical and Computer Engineering, Florida International University, Miami, Florida 33199. Florida International University is a state university located in two suburban areas in Miami with over 24,000 students, of which 1,800 upper division and graduate students are enrolled in the College of Engineering. The School of Engineering has four departments: Electrical and Computer, Civil, Mechanical, and Industrial Engineering and is an Equal Opportunity/Equal Access Employer and Institution.

The Electrical and Computer Engineering

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Department of the University of South Carolina invites applications for faculty positions in the areas of artificial intelligence, computer architecture and computer vision. Applicants must have a Ph.D. in either Electrical Engineering, Computer Engineering or Computer Science. Applicants must have legal authority to work permanently in the U.S. The University of South Carolina, as the flagship university of the state, seeks candidates having a strong commitment to excellence in both education and research. Successful candidates are expected to demonstrate strong research potential. Please submit complete resume and the names of three references to Professor Ronald D. Bonnell, Electrical and Computer Engineering Department, University of South Carolina, Columbia, SC 29208. Closing date for applications is February 1, 1992. The University of South Carolina is an Affirmative Action/Equal Opportunity Employer.

Faculty, Department of Electrical and Computer Engineering, Florida International University, A State University of Florida at Miami. Nominations and applications are invited for tenure track faculty positions (Assistant/Associate/Full Professor) in power, computer engineering, and electrical engineering. The Department of Electrical and Computer Engineering at F.I.U. the largest department in the College and offers B.S. (accredited), M.S., and Ph.D. degrees in electrical and computer engineering. Qualifications: Earned doctorate with a strong record of funded research, preferably from government agencies, desire to direct and assist young faculty in obtaining funded research. Also evidence of experience in other scholarly areas, including publications and teaching. Rank and salary are commensurate with qualifications and experience. Applications and Dates: All applications received prior to January 1992 receive full consideration. The positions will be available starting August, 1992. U.S. citizens or lawfully authorized alien workers should send a letter addressing the qualifications above, a resume, and three references (names) to: Dr. Wunnava V. Subbarao, Chair, Search and Screen Committee, Department of Electrical and Computer Engineering, Florida International University, Miami, Florida 33199. Florida International University is a state university located in two suburban areas in Miami with over 24,000 students, of which 1,800 upper division and graduate students are enrolled in the College of Engineering and Design. The School of Engineering has four departments: Electrical and Computer, Civil, Mechanical, and Industrial Engineering and is an Equal Opportunity/Equal Access Employer and Institution.

The School of Electrical Engineering and Computer Science at Washington State University invites applications and nominations for a faculty position in analog electronics. This is a full-time, 9 month, tenure-track faculty position to be filled at the assistant, associate or full professor rank. The individual sought to fill the position must hold a doctoral degree. The electronics program has traditionally been an important one in the College of Engineering at Washington State University, enjoying the support and respect of many leading industries. Recently, the School has established an NSF university/industry Center for the Design of Analog/Digital Integrated Circuits (CDADIC) with 14 participating industrial companies. The successful applicant will actively interface with the Center personnel and its research programs. In addition the person filling this position should: 1) Establish and carry out a program of funded research in a significant area of analog electronics, 2) teach courses at both the graduate and undergraduate levels, 3) interact favorably with industry and federal agencies. Letters of nomination and/or applications for this position should be sent to: Dr. Yacov Shamash, Professor and Director; School of Electrical Engineering and Computer Science; Washington State University; Pullman, WA 99164-2752; (509) 335-8148. Applications should include a complete professional vita and a list of references. Final screening will begin February 1, 1992 and will continue until the position is filled. WSU is an EO/AA educator and employer. Protected group members are encouraged to apply.

Drexel Fellowships in Biomedical Engineering and Science. Drexel Fellowships in Biomedical Engineering and Science are supported by the Calhoun Endowment. Students can specialize in the following areas: artificial organs, bioinstrumentation, biomedical imaging and signal processing, biomedical science, biomaterials, biomedical systems and control, cardiovascular dynamics, diagnostic ultrasound, sensors and electrodes, biomechanics and rehabilitation. Each Fellowship includes a minimum stipend of $10,000 for a 12 month appointment beginning Fall, 1992. With a waiver of all tuition and fees this award is worth approximately $22,000. Deadline for application is February 28, 1992. For application write: Dr. John M. Reid, Acting Director, Biomedical Engineering and Science Institute, Drexel University, Philadelphia, PA 19104.

University of Colorado at Denver. Dean, College of Engineering and Applied Science. The University of Colorado at Denver invites applications and nominations for the position of Dean of the College. The College has departments of Civil Engineering, Computer Science, Electrical Engineering, and Mechanical Engineering, and has strong undergraduate programs. The comprehensive M.S. programs attract many working students from local industry and federal laboratories. The Ph.D. degree, offered in conjunction with the University of Colorado at Boulder, is a key element of a strong and growing research program at the University of Colorado at Denver. The University, in the heart of the city, is one of four campuses of the University of Colorado System and shares a modern 169-acre campus with Metropolitan State College of Denver and the Community College of Denver. Total campus enrollment of all three institutions exceeds 30,000 students. The College has 40 full-time faculty augmented by adjunct faculty and 11 staff members to serve 706 undergraduate and 232 graduate students. The College is seeking a leader who will provide vision for the College; who is able to interact well with students, faculty, and staff; and who has demonstrated a commitment to increasing diversity within the academic community. He/she must have an earned doctorate or equivalent in engineering or a cognate field and must have an established scholarly record to be appointed as a tenured full professor in the College. Strong interpersonal, communication, and managerial skills are required along with demonstrated experience in external fund-raising. Experience working with industry is desirable. Applicants and nominees should submit a letter summarizing qualifications, a current vita, and the names, addresses, and telephone numbers of at least three references to: Dr. Camila Alire, Chairperson, Engineering Dean Search Committee, Campus Box 101, University of Colorado at Denver, P.O. Box 173364, Denver, CO 80217-3364, (303-556-3521). Additional information is available upon request to the Chair. Review of applications will begin on January 15, 1992, and continue until the position has been filled. The University of Colorado at Denver is committed to diversifying the administration, faculty, and staff and strongly encourages applications from protected class members.

Purdue University School of Electrical Engineering invites applications for tenure-track faculty positions at all ranks. Primary need is for faculty with specialization in the areas of computers, microelectronics, and optics; but all specialities will be considered. Responsibilities will include both teaching and research. Salary is commensurate with qualifications and experience. Applicants must possess a doctorate degree. Send a resume, including a statement of teaching and research interest and a list of three (3) references to: Head, School of Electrical Engineering, Purdue University, West Lafayette, IN 47907. Purdue University is an Equal Opportunity/Affirmative Action employer.

Faculty Positions—Massachusetts Institute of Technology. The Department of Electrical Engineering and Computer Science seeks candidates for faculty positions starting in September 1992. We anticipate openings for several junior faculty appointments for individuals who are completing, or who have recently completed, a doctorate. Senior faculty positions may also be available in some areas. Faculty duties include teaching at both the graduate and undergraduate levels, research, and supervision of theses. We are interested in candidates in most areas of electrical engineering and computer science, including artificial intelligence, communications, computer systems and languages, design and manufacturing, energy, and theory of computation. All candidates should write to the address below, describing their professional interests and goals. Each application should include a curriculum vitae and the names and addresses of three or more references. Additional material describing the applicant's work, such as papers or technical reports, would also be helpful. All candidates should indicate citizenship and, in the case of non-US citizens, describe their visa status. Send all applications to: Prof. F.C. Hennie, Room 38-435, Massachusetts Institute of Technology, Cambridge, MA 02139. M.I.T. is an equal opportunity/affirmative action employer.

Faculty Positions in Electrical Engineering, University of Washington. Applications are invited from highly qualified, research oriented candidates in all areas of electrical engineering. The Department anticipates that several tenure-track positions, most likely at the assistant professor level, will be available for appointment during the 1992-93 academic year. We especially encourage women and minority candidates to apply. Send resume with names of four references to Faculty Search Committee, Department of Electrical Engineering FT-10, University of Washington, Seattle, WA 98195. The University of Washington is an equal opportunity/affirmative action employer.

Bioengineering Faculty Position at Arizona State University. ASU's College of Engineering and Applied Sciences intends to seek applicants at all levels for a tenure-track faculty position in Bioengineering. Appointment at either the assistant, associate or full-professor level will be considered depending upon the qualifications of the applicant. In addition, the nomination or application of individuals qualified as "Eminent Scholars" are also encouraged. Arizona's Eminent Scholars Program is designed to attract individuals of national prominence with special salary compensation. All areas of research interest will be considered, however, individuals with research programs in biomechanics, biomaterials, or medical imaging or artificial organs are preferred. Candidates must hold a Ph.D. in Bioengineering or Biomedical Engineering, or hold a Ph.D. in another Engineering discipline with a history of research activity in Bioengineering or Biomedical Engineering. Candidates will be expected to teach both graduate and undergraduate courses and to develop a funded program of Bio/Biomedical Engineering Research. We encourage applications from women and members of minority groups. Interested candidates should contact: Dr. Eric J. Guilbeau, Chair of the Search Committee, Department of Chemical, Bio and Materials Engineering, Arizona State University, Tempe, Arizona 85287-6006.

University of Virginia Department of Systems Engineering—Extension of Deadline. The deadline for applications for the faculty position announced in this journal in January 1991 has been extended to February 1, 1992.

University of Hong Kong, Reader/Senior Lecturer in Electrical and Electronic Engineering (Ref. 91/92-2). Applications are invited for a Readership/Senior Lectureship in the Department of Electrical and Electronic Engineering. Applicants should possess a higher degree, and/or corporate membership of the Institution of Electrical Engineers or its equivalent. Preference will be given to those having substantial teaching, research and other relevant experience in one of the following fields: Digital Signal Processing and Data Communications. Annual salaries (superannuable) are on the scales: Reader: HK$501,120—665,700 (9 points); Senior Lecturer: HK$480,360—645,300 (9 points) (approx. US$1 = HK$7.70 as at September 30, 1991.) Starting salary will depend on qualifications and experience. At current rates, salaries tax will not exceed 15% of gross income. Housing at a charge of 7.5% of salary, children's education allowances, leave, and medical benefits are provided. Further particulars and application forms may be obtained from Ap-

pointments (39959), Association of Commonwealth Universities, 36 Gordon Square, London WC1H OPF, UK; or from the Appointments Unit, Registry, University of Hong Kong, Hong Kong, (Fax (852) 5592058; E-mail: APPTUNIT@HKUVM1.HKU.HK). Closes 10 January 1992.

Computer Engineering Department, San Jose State University, invites applications for tenure track faculty positions. Earned doctorate in Computer or Electrical Engineering is required. Positions are limited to US Citizens or Permanent Residents. Areas of interest are (1) Network Design, (2) Microcomputer Design, (3) Operating System and Smart Compiler Design, and (4) Software Engineering. The major goals are graduate course development and establishment of a research program in the area of interest. Three or more years of relevant industrial experience are desirable. Rank and salary consistent with qualifications and experience. Open period is from 11-1-91 until positions are filled. Please send a letter of intent explicitly stating your area(s) of interest, a copy of your most significant peer reviewed publication (or a significant abstract of your recently completed Dissertation) related to your area(s) of interest, a complete curriculum vitae, and names and telephone numbers of three references to Dr. Nicholas L. Pappas, Chair, Computer Engineering Department, San Jose State University, San Jose, CA 95192-0085. SJSU is an equal opportunity, affirmative action, Title IX employer.

Faculty Positions in Electrical Engineering. Two full-time, regular positions. Description—Teaching at undergraduate and graduate levels. Research in the field of specialization and experience in supervising graduate students. An active role in administration and service to the community. Qualifications—Applicants must hold a PhD in electrical engineering, engineering physics, or a related area. They should also be good communicators and demonstrate a distinct interest in both teaching and research and development. Mastery of written and spoken French is required as is membership, or eligibility for membership, in the Ordre des ingenieurs du Quebec. Specific Requirements—Specialization in the field of integrated circuit is necessary for active participation in the University's microelectronics research group, which is engaged in developing new electronic devices and/or materials. Relevant experience in the fields of microelectronics and engineering physics are requisites. Applicants should send a curriculum vitae and the names of three referees by no later than 4:00 p.m. on Monday, January 6, 1991 to: Monsieur le Doyen, Faculte des sciences appliquees, Concours 91-1-25. (819) 821-7111 (telephone); (819) 821-7903 (fax). Employment conditions are governed by existing collective agreements. In accordance with Canadian immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada. The Universite de Sherbrooke is an equal opportunity employer.

The Chinese University of Hong Kong invites applications for Senior Lecturer/Lecturer positions in the Faculty of Engineering in the following areas. Department of Computer Science: theoretical computer science, distributed processing, multi- lingual open systems, real-world information and knowledge systems, graphics and computer visualization; Department of Electronic Engineering; opto-electronics, VLSI circuits and systems, VLSI CAD; Department of Information Engineering: optical communications and communication networks; Department of Systems Engineering: systems analysis and optimization, robotics, integrated manufacturing systems and system automation. Applicants should have a Ph.D. with a strong research and publication record and a commitment to both undergraduate and graduate teaching. Successful candidates are expected to initiate a research program of value to Hong Kong and its industries. Internal and external funds are available to support both theoretical and experimental research. The Faculty is equipped with a network of some 200 workstations with access to Bitnet and Internet. Salaries are competitive and the total compensation is comparable to that in the U.S. Appointees will receive benefits that include passage, baggage allowance, leave with full pay, housing subsidy, medical care, superannuation or gratuity. Please send full resume, names of three references and a brief research plan to Professor Omar Wing, Dean, Faculty of Engineering, The Chinese University of Hong Kong, Shatin, Hong Kong. Fax: (852) 603-5701. E-mail:owing@eng.ie.cuhk.hk.

Research Center Director—The Thomas J. Watson School of Engineering and Applied Science at the State University of New York at Binghamton seeks a director for the Integrated Electronics Engineering Center (IEEC), a newly established State/Industry/University Cooperative Research Center funded by the National Science Foundation, the State of New York, and private industry. The Center performs research and advanced engineering in the broad field of electronics packaging and is expected to grow significantly in the next few years. The director should hold an earned doctorate and must qualify for a tenured professorship in electrical, mechanical or industrial engineering. While experience in the broad field of electronics packaging is highly desirable, candidates whose experience is in one of the sub-fields of packaging will be considered. While the director will do some teaching and research, it is expected that the principal activity will be direction and development of the Center. Thus, good managerial and communication skills are essential. Since the Center is funded from federal, state, and industrial sources, the director must be able to work effectively with diverse external constituencies as well as university faculty and administration. The State University of New York at Binghamton is strongly committed to affirmative action. We offer access to services and recruit students and employees without regard to race, color, sex, religion, age, disability, marital status, sexual orientation or national origin. Applications should be received by January 15, 1992 to receive full consideration. Please direct nominations and applications—including the names and addresses of three references to: Lyle D. Feisel, Dean, The Thomas J. Watson, School of Engineering and Applied Science, State University of New York at Binghamton, P.O. Box 6000, Binghamton, New York 13902-6000.

Government/Industry Positions Open

Senior Process Engineer. Design & simulate sub-quarter micron CMOS devices & process; conduct test pattern mask set design, layout & procurement; develop process steps; fabricate, characterize, model & analyze devices; characterize, model & design advanced III-V compound devices; perform analytical characterization, novel process design & modeling of nonequilibrium behavior in scaled devices. Ph.D. in Electrical Engineering or Electrical Engineering and Computer Science. Academic project/research background in solid state device physics & technology, including MOSFET silicon devices and GaAs device processing using IC fabrication equipment including diffusion furnace, patterning and thin film deposition; also silicon, GaAs device and material characterization using electrical & analytical characterization techniques including HP equipment, TEM and SEM, semiconductor process & device simulators including Suprem and Pisces and computer programming in Basic, Fortran and C. $4,685/mo.; 40 hrs./wk. Place of employment and interview: Santa Clara, CA. If offered employment, must show legal right to work. Send this ad and your resume to: Job Number PM10318, P.O. Box 9560, Sacramento, CA 95823-0560 not later than December 31, 1991. The company is an equal opportunity employer and fully supports affirmative action practices.

Engineer, Senior Process. Develop manufacturable metallization processes for multi-chip module technology; conduct experimental and theoretical modeling of materials interaction and impact on process reliability. Ph.D. or completion of all Ph.D. requirements but dissertation in Materials Science or Materials Science and Engineering or Electrical Engineering. Academic project/research background in semiconductor processing, including modeling, simulation & investigation of interactions/phase formation in thin-film metallization schemes using Transmission Electron Microscopy, X-Ray Diffraction & Rutherford Backscattering; also thin-film fabrication using Physical Vapor Deposition processes, CMOS IC fabrication and testing, Unix & Pascal; academic coursework in microstructural characterization & stress analysis. $4,675/mo.; 40 hrs./wk. Place of employment and interview: Santa Clara, CA. If offered employment, must show legal right to work. Send this ad and your resume to: Job No. FC17223, P.O. Box 9560, Sacramento, CA 95823-0560 not later than December 31, 1991. The company is an equal opportunity employer and fully supports affirmative action practices.

Sabbatical or Post-Doctoral Researcher (finite or boundary element analysis in electromagnetic fields): To conduct independent research in the above field. Requires: PhD in this field. 1-2 years visiting position, 50% business hours of which can be spent in other academic facilites in Japan. Round-trip airplane tickets to Japan, hotel fees and train tickets for domestic business trips in Japan during the stay, and company dormitory with dining service are provided freely. Send e-mail to yoda@ele.crl.melco.co.jp, or write to Kiyoshi Yoda, Mitsubishi Electric Corporation, Central Research Laboratory. 8-1-1 Tsukaguchi Hommachi, Amagasaki 661 Japan. Located near Kyoto and other nice places to try.

Cardiac Pacemakers, Inc. a leader in the development and technology of life sustaining cardiac pacemakers and implantable cardiac defibrillators has an opening for an Associate Product Manager. Associate Product Manager responsibilities include developing and implementing marketing strategies for programmers and other external instrumentation relating to pacemakers and defibrillators. Liaison activities and training of sales, field and professional medical personnel; assistance with and coordination of manufacturing, distribution and inventory issues. Coordination of such company functions as research and development, quality assurance, manufacturing and finance. Education and experience requirements: B.S. in electrical engineering and M.B.A. minimum; at least one year experience in new product planning in pacemaking and defibrillator manufacturing fields. Salary: $4000 per month. Please reply to S. Springmeyer, Minnesota Department of Jobs and Training, 390 No. Robert Street, Room 124, #1-238, St. Paul, MN 55101. An equal opportunity employer.

Electrical Engineering Manager—Will be responsible for electrical engineering department including training & instructing new staff in complex engineering design of injection molding machines and customers in use of the machines; will perform engineering functions as needed. Responsible for design of parts handling equipment, peripheral support equipment & related accessories; design of machines for specialized molding applications, statistical process control & quality control programming and use applications; application & optimization of new software, processing & programming of technology for field applications; and processing design of specialty software. Requires Bachelor's or equivalent in Electrical or Mechanical Engineering Technology and either 5 yrs. exp. in the job described or 5 yrs. exp. managing an electronic test group in injection molding machine plant. Qualified applicants should apply with resume to: The York Job Service Office, 140 North Duke St., York, PA 17405. Refer to Order #4448890.

Chief Engineer; 8:00 a.m. - 5:00 p.m.; $49,000/year; Overtime as needed. Job requires: Master degree with major field of study Electrical Engineering and 7 years working experience in related field. Job also requires: 1) 1 graduate level course in computer circuit development; 2) 1 graduate level course in simulation methods; 3) 1 graduate level course in operating systems. Job duties: Perform control systems design and analysis on industrial

products and diesel engines. Design and develop control system software programs for diesel engine fuel systems and other applications. Design and develop digital control circuitires and hardwares for various applications. Qualified applications should send resume and verification of requirements to: 7310 Woodward Avenue, Room 415, Detroit, Michigan 48202. Reference No. 74491. Employer Paid Ad.

Electrical Engineer. 40 hr. work week. Rate of pay—Basic $20/hr, O.T. $30/hr. Job requires Masters Degree in Electrical Engineering. In addition, a minimum of 16 graduate credit hours should be in classes involving circuit theory; utilizing computer aided simulation programs. Job involves the design of automotive electrical circuitry utilizing SYSCAP to conform to the specifications and requirements of auto design. Simulate, design, troubleshoot and prepare written technical reports. Send resumes to 7310 Woodward Ave., Room 415, Detroit, MI 48202 - Reference No. 64191. Employer paid ad.

Sales Engineer for Mechanical and Electrical Equipment for Technical Equipment Export Co. in N.E. Ohio to direct export sales of technical equipment for oil, power and construction industry in Europe and the Middle East through performance of the following duties: Make technical presentations of company's products, equipment and technology to prospective and existing customers; assess customer needs and make sales quotations based on customer's requirements and specifications; negotiate contracts incorporating customs regulations, tariffs and international payment terms; consult with customer's engineering and technical staff to assure compliance with customer's needs and specifications. M.S. in Electrical Engineering. No exp. required but candidate must be willing to travel to Europe and the Middle East every two months, travel not to exceed 30%. Must have ability to speak, read, and write Arabic, 40 hrs./week, 9am-5pm, $31,920/yr. Must have proof of legal authority to work permanently in U.S. Send resume in duplicate (no calls) to J. Davies, JO# 1206006, Ohio Bureau of Employment Services, P.O. 1618, Columbus, OH 43216.

Electrical Engineer wanted. Duties: Computer simulation and analysis of automotive electrical systems and components using SABER software for electrical circuit simulation, and making design recommendations to eliminate problems. Requirements: Master's in Electrical Engineering, 2 yrs exp as Electrical Engineer or Graduate Assistant. Related exp. must include research in automotive powertrain electronics and the design and simulation of electronic circuits using HSPICE and SABER simulation software (or teaching the same). Must have 3 graduate courses in VLSI design and academic research in engine misfire detection. Pay is $3,300 per month. 40 hr/wk. Resumes to 7310 Woodward Ave., Rm 415, Detroit, MI 48202. Ref. #70591. Employer Paid Ad.

Engineer II for NE Ohio education/research facility to apply system theory & electrical engineering knowledge to analysis & design of hardware & software for 3-D graphics (MR angiography) & medical image processing (cardiac imaging), utilizing high performance graphics system. Design 3-D graphics for biological application & processing of data from image scanners such as CT, SPECT, & MRI. Establish mathematical models to describe complex physical processes & handle large database management problems, utilizing Fortran, & C in a Unix or VMS operating system. Utilize high field MRI & SPECT scanner for multimodality studies. Prepare projects & reports. 3 yrs. exp. req. in above duties & B.S. in Systems Engineering or 6 mos. exp. in computer graphics & development of 3-D imaging system using MRI in medical applications & M.S. in Systems Engineering (exp. may be gained during or after degree). Must have at least 1 course ea. in adaptive pattern recognition & neural networks, use of neural network computers, mathematics of imaging in industry & medicine, physics of imaging applications to industry & medicine, spectral analysis of random signals, chemical spectroscopy & system identification. M-F, 8:00AM-5:00PM, $35,000/yr. Must have proof of legal authority to work permanently in U.S. Send resume in duplicate (No Calls) to J. Davies, JO #1206005, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, OH 43216.

Research Engineer—Electromagnetic Analysis —Electrical Machines. GE Canada's Engineering Laboratory carries out applied research and development for world product mandate businesses such as large industrial motors and hydroelectric generators. The Laboratory has expertise in electromagnetics, heat transfer and ventilation, metallurgy and chemical and insulation systems. The position of a research engineer in electromagnetics is open to the qualified candidates. Minimum qualification is a Ph.D. in electrical engineering from a recognized university. Industrial experience and background in rotating electrical machines and in-depth knowledge of numerical analysis and modelling of electromagnetic fields are required. The incumbent of the position will have opportunities to verify new simulation and modelling techniques by laboratory tests on experimental machines and special factory tests on production machines. The successful candidate will receive outstanding compensation and benefits. The position has full growth potential in a professional career band. Please forward your resume in strict confidence to Dr. H.C. Karmaker, Leader, Electromagnetics Team, Engineering Laboratory, 107 Park Street North, Peterborough, Ontario K9J 7B5, Canada. GE Canada is an equal opportunity employer.

Warranty Data Analyst to track warranty information for Reliability Engineering Department; analyze data and recommend modifications and confer with on site engineers. Require Bachelor of Science degree in Electrical Engineering. Bachelor's level coursework must include the following: 1) Computer Organization; 2) Computational Engineering Methods; 3) Control Systems; and 4) Engineering Materials. 40 hour work week—8:00 a.m. to 5:00 p.m. $30,160.00 per year. Employer paid ad. Send resumes to 7310 Woodward Avenue, Room 415, Detroit, Michigan 48202. Reference No. 84991.

Electrical Eng.—Supv. R&D group dealing with radiowave propagation studies related to satellite commun. Work involves: modelling of prop. phenomena; design, deploymt. & data anal. of prop. experimts; design & implement. of prop. impairmt. countermeasure techniques; participate in int'l committees, such as CCIR, to establ. engrg. guidelines on prop.-related matters. Knowl. of comp. languages (Fortran, Pascal, Assembly); knowl. of VAX VMS, IBM-PC, DOS, & Unix. Rqmts: Ph.D. in Radiowave Propagation & 4 yrs. exp. as Prop. Eng. M-F, 40 hr./wk., 8:30- 5:00; Sal: $72,000/yr. Mail resume & copy of ad to MD DEED, 1100 N. Eutaw St., Rm. 212, Balto., MD 21201; JO #9049030; Job Loc: Clarksburg, MD.

Assistant Staff Investigator Digital Imaging Systems. Non-profit health care education, research and hospital center seeks Assistant Scan Investigator Digital Imaging Systems to conduct research on transform image compression techniques for digital radiographs. Design and implementation of full frame transform compression algorithms for picture archiving and communication system (PACS) in digital radiology department. Develop computer network system for X-window based radiographic image viewing. Investigate image processing techniques for computer aided diagnosis system of mamograms. Design and conduct radiographic observer study for image quality evaluation of image compression algorithms and image digitization systems. Prepare research results for publication, conferences; develop research funding proposals. Min. Qual. Ph.D. in Electrical Engineering, Ph.D. must include dissertation in Digital Image Processing and data compression; (1) year experience Research Assistant, must include (6) months or more radiographic imaging research using object detection and estimation theory. $32,680/year; 8:30 am-5:30 pm/M-F. Resume to: Michigan Employment Security Commission, 7310 Woodward Ave. Rm 415, Detroit, MI 48202 Ref. No. 69091. An Equal Opportunity Employer Paid Ad.

Supervisor of Development Engineering Group needed by Telecommunication Power System firm to supervise design engineers and technicians performing analog and digital electrical engineering, software engineering and mechanical engineering; oversee department support of systems engineering development specifications, department component specifications and qualifications functions, technical specifications derivations, technical support for manufacturing engineering and customer service. Will also develop component Incoming inspection requirements, estimate project costs, oversee customer training courses, perform applied research and write two technical publications per year for IEEE journals. Must have Ph.D. Electrical Engineering, major in Power Electronics, including four years research experience researching DC/DC, DC/AC, AC/DC and UPS pulse width modulated power supplies; two years project management experience in the telecommunications power electronics industry including recent conference presentations and journal publications in field. $70,000 per year, 40 hrs/week in Seattle, Washington. Send resume by Dec 31st to: Employment Security Dept., ES Div., Job Order #288204, Olympia, WA 98504.

Development Engineer: Apply mats. sci. & elec. engineering bckgd incl'g defect chem. to conduct experiments & investigations in solid state physics/chem. & electromagnetic compatibility theory in conjunction w/ analytical electron microscopy to develop advanced new areas of EMC technologies invol'g new mats. exploration & characterization. New product designs associated w/interconnection components & subsystems to support electromagnetic interference control & information transmission. Research into new ceramic materials & characterization of material properties. Emphasis on experiments & modelling of EMI controlled interconnection systems. Computer modelling for signal transmission properties & qualities. Define, plan & implement projects in new areas of EMI controlled interconnection systems. Req: Ph.D. mats. sci., EE degree & 2 yrs. exp. w/ext bckgd in defect chem., ceramic processing & characterization of microstructures & microchemical analysis. Bckgd in effects of mat. properties on signal behavior & application of electrical measurements optimizing electrical properties with respect to EMC/EMI. Exp. in failure analysis invol'g fatigue, creep, finite element analysis for stress/straindistribution & mech. testing skills. Proven research & publications bckgd. Research invol'g processing & fabrication of ceramic mats. Incl'g synthesis of new matls & synthetic approaches & high resolution electromicroscopy & analytical electronmicroscopy. 40 hrs/wk; $47,040/yr; contact or send resume to Harrisburg Job Service Office, 2971 N. 7th St., Harrisburg, PA 17105 (717) 783-3270; JO #4287735.

Senior Research & Development Engineer—Perform research & development for semiconductor micro-sensors. Design, analyze, simulate, fabricate, assemble & test sophisticated semiconductor devices. Prepare photomask design, silicon etching, wet chemical processing, thin film deposition, thin film measurement, silicon fusion bonding, eutectic die bonding, wire bonding & parametric testing. Prepare necessary reports. Keep current with all developments in the field. 40 hrs/wk, 8:30am—5pm. $50,000/yr. Must have 7 years of college. Must have Ph.D. degree in Electrical Engineering. Coursework must include courses in Integrated Circuits and Semiconductors. Must have 1 month experience in the position offered or 2 years experience as a Teaching Assistant and/or Research Assistant. Experience must include work on silicon micromachining & semiconductor sensors. Must have proof of legal authority to work permanently in the U.S. Send resume to: Illinois Department of Employment Security, 401 South State Street—3 South, Chicago, IL 60605, Attn: L. Boksa, Ref# V-IL-3225-B. No Calls. An Employer Paid Ad.

Research Engineer in crystal growth facility, $31,600/yr, 40 hrs/wk. Will generate and implement unique algorithms for control system on Digital Equipment MicroVAX II/IEEE 583 Standard CAMAC Interface for use in epitaxial growth of A1GaAs/GaAs and A1GaInAs/GaAs crystals. Responsible for designing and upgrading all computer programming and maintenance of MOCVD automatic control system, MOCVD reactor machinery, and other research equipment. Will conduct research activities in

coordination with faculty members. Will supervise and train research assistants in the use of MOCVD equipment. Master's degree in electrical engineering required with coursework in computer engineering. Must have two years experience in A1GaAs/GaAs and A1GaInAs/GaAs crystal growth by using MOCVD controlled by Digital Equipment MicroVAX II/IEEE 583 Standard CAMAC Interface. Submit resumes to New Mexico Dept. of Labor, 501 Mountain NE, Albuquerque, NM 87102. CC#1001. JO #334034.,

Electronics Research Engineer to develop metalorganic chemical vapor deposition (MOCVD) for the growth of GaAs and InP-based epitaxial films for optoelectronics and electronic device applications. Specifically research will be in the field of III-V compound semiconductor epitaxy using organometallic vapor phase epitaxy (OMVPE) to form multilayered epitaxial structures for application to the study of charge transport in superlattices, to discrete light emitting devices and to the development of optoelectronic integrated circuits (OEICs) in which solid state transistors, detectors, and laser device functions are integrated into a monolithic single chip of III-V semiconductor. Job duties include publishing in professional journals regarding specific research and publishing on broader topics in collaboration with colleagues; working with highly toxic/hazardous materials; applying graduate-level physics, chemistry, and heterostructure electronic device operation principles to film growth and characterization in the above mentioned semiconductor materials. Characterization duties to include Hall effect, photoluminescence, and X-ray diffraction measurements. Requirements: Ph.D. in Electrical Engineering or Materials Science (or Materials Physics and Radiation) and two years semiconductor research experience. Graduate research must specifically include MOCVD growth and characterization of III-V materials. Two years experience must be in MOCVD growth and epitaxial film characterization. Characterization skills must include ability to assess and understand the crystallographic, electrical and optical properties of multilayered epitaxial films and their influences on the electro optical device performance. $56,200 per year/40 hr. wk. Job in Tempe, AZ. Qualified applicants send resume with ad by December 20, 1991 to AZ Job Service, Attn: 732A Re: 5406976, P.O. Box 6123, Phoenix, AZ 85005. Emp. Pd. Ad. Proof of authorization to work in U.S. required if hired.

Computer Engineer for consulting firm to be assigned to Columbus, Ohio. Design, develop, implement, test and maintain complex real-time Unix applications on fault tolerant hardware for communications. Projects include: network management system; real time database applications. Tools: Case tools; X.25 network protocol; C++; Unix; Sun Workstation. MS in Electrical and Computer Engineering as well as 1 year experience in the job described or as a Software Engineer required. Additional six months experience with X.25 network protocols; TCP/IP; device drivers; object-oriented programming. Graduate education must include one project with Unix on Sun Workstation. 40 hrs/wk. 9:00am—5:00pm, $42,000/yr. Must have proof of legal authority to work permanently in the U.S. Send resume in duplicate (no calls) to J. Davies, JO#1260327, Ohio Bureau of Employment Services, PO Box 1618, Columbus, OH 43216.

R&D Engineer wanted. Duties: Develop new vehicle lighting systems, using lens design techniques, non-image optical techniques, fiber optics, holographic optical elements, light emitting diodes; designing lighting systems, using optical design packages, image processing systems and CAD packages; prototype testing and engineering evaluation of new products; identify and analyze product deficiencies and design problems, develop engineering conclusions and recommend design modifications to correct product problems. Set up an optical laboratory for photometry test and optical design. Requirements: Ph.D. in Electrical Engineering concentrating in Optics. Ph.D. thesis research must have included optical design & image processing. Academic research must have included working in the field of optical image processing, geometric & non-image optics making dichromatic gelatin holograms & using each of the following equipment: laser scanning system for computer generated holograms; computer based optical image processing systems; electro-optical hybrid pattern recognition systems; white light image processing systems; fringe stabilized holographic system for dichromatic gelatin holograms; liquid crystal light valve & liquid crystal display devices; programming in at least two high level languages, laser tuneup & maintenance techniques & ray tracing using digital computers. Pay is $50,490 per yr. 40 hr/wk. Resumes to 7310 Woodward Ave., Rm 415, Detroit, MI 48202. Ref. #68291. Employer Paid Ad.

Associate Scientist I/II. The National Center for Atmospheric Research (NCAR) in Boulder, Colorado, seeks an Associate Scientist I/II for active and passive remote sensing research. NCAR has excellent remote sensing instrumentation and computing facilities, including the CRAY supercomputer and SUN workstations. You will analyze microwave radar and satellite data, and will work with electromagnetic scattering, propagation and radiative transfer models. Level II duties include working with rigorous electromagnetic scattering, propagation and radiative transfer models. Observations made using multifrequency polarimetric radars and radiometers will be analyzed in conjunction with model results. Level I requirements: B.S. in atmospheric science, a physical science or electrical engineering; skill in active and passive remote sensing research; knowledge of Doppler radar and satellite data analysis. Level II requirements: M.S. in atmospheric science, a physical science or electrical engineering; demonstrated skill and knowledge in the above areas plus skill in using radar and radiative transfer models. Salary range: Level I, $2,393—$3,590/mo; Level II, $2,760—$4,140/mo. The closing date for this position is 5:00 p.m., December 31, 1991. Send resume for Job #1504 to: Searl G. Brier, Human Resources Administrator, UCAR/NCAR, P.O. Box 3000, Boulder, CO 80307. UCAR/NCAR is an EEO/AA Employer.

ROV Engineer—Degn custmzd ROV tools for subsea engnrng ops & operate ROVs offshore. Dvlp prevntv & correctv maintnce plns; prfrm hydraulic & elctr modifications & dsgn interface tooling to integrate machinery w/subs. Suprvs & train ROV crew in the operation, maintnce & repair of 7 & 9 fnction manipulators, stndrd bus/minibus microproces ctrl systm using Intel technlgy, closed loop boosted hydraulic fluid systm, CCD & SIT video camera systms. Req: BS in Electronics Eng. & 2 yrs exp in job or 2 yrs exp as ROV Engineer. Sal: 865.38/wk; 40 hrs/wk. Apply at Texas Employment Commission, Houston, TX, or send resume to Texas Employment Commission, TEC Bldg., Austin, TX 78778, J.O. #6422218. Ad Paid by an Equal Opportunity Employer.

Monterey Bay Aquarium Research Institute—Postdoctoral Fellows. MBARI invites applications in the fields of biological, chemical and physical oceanography and in ocean engineering. Selection will be made on a competitive basis with particular emphasis on the integration of enabling technologies into oceanographic research. Awards are for one year, with the possibility of renewal for a second year, and may begin any time between June 1992 and Dec. 1992. Send: a curriculum vitae; names and addresses of at least three references; transcripts of undergraduate and graduate academic records; a succinct description of doctoral research; and a concise statement of research interests, including the nature of the research project to be pursued at MBARI. MBARI provides opportunities for innovative, technology-based ocean research. The Institute has balanced programs in engineering and science, with a goal of developing new technology in the conduct of oceanographic research. MBARI operates a 110' research vessel as the surface support ship for our ROV and for hydrographic work in Monterey Bay. The Bay contains four established mooring sites in the Monterey Submarine Canyon, which brings the deep sea environment to within a few miles of our laboratories. Apply by Jan. 15, 1992 to: PFP, MBARI, 160 Central Ave., Pacific Grove, CA 93950. AA/EOE.

The EPRI Power Electronics Applications Center (PEAC), Knoxville, TN, is looking for a Senior Power Electronics Engineer. The mission at PEAC is to expedite commercialization and technology transfer to advanced power electronics technologies for the electric utility industry. Work experience in power electronics circuit design, testing, and trouble shooting are required. The newly created position requires strong utility power system background and power electronics circuit design experience. Responsibilities include: Engineering design of advanced high frequency power circuits. Advanced power semiconductor evaluation. Analysis and simulation of the interface power electronic circuit utility power system. Interface analysis & simulation. The successful candidate should possess advanced degree(s) in electrical engineering with emphasis in power electronics and power systems. Experience in project management is a plus. Salary is in the range of $50,000 to $70,000 (plus a 20% Fringe benefits package) depending upon education, experience and performance. Respond to: IEEE SPECTRUM, Box No. 12-1, 345 East 47th St., New York, NY 10017.

Project Engineer; 40 hours/week; 8:00 a.m.-4:30 p.m.; $38,000/year. Job requires: Master of Science in Electrical Engineering degree with a major in Electromagnetics. Job also requires: 1) Graduate level research in which applicant performed analysis, design, construction, & testing of Radio Frequency components & detecting systems as evidenced by Master's thesis; 2) Graduate level research in which applicant used spectrum analyzers & microwave network analyzers as evidenced by Master's thesis; 3)1 grad. course in antennas; 4) 1 grad. course in microwave networks; 5) 1 grad. course in microwave electronics; and 6) 1 grad. course in fields and waves or wavesguides. Job duties: Perform analysis and provide consultation to achieve electro-magnetic compatibility (EMC) in vehicles. Use principles of EMC circuit analysis to perform design reviews on electronic components and systems during the design and development phase to ensure electromagnetic compatibility. Present seminars. Support EMC testing. Instruct and oversee technicians. Assist customers in defining test procedures and performance objectives in a cost-effective manner. Troubleshoot and prepare test instrumentation. Develop/improve EMC test methods. Specify and evaluate special high and very high frequency instrumentation. Develop/improve software for automotive instrument control. Model EMC problems using C programming language in a UNIX environment. Provide technical expertise to technicians, testers, and customers on test methods, instrumentation, and instrument control. Review and interpret test results. Qualified applicants should send resume and verification of requirements to: 7310 Woodward, Rm 415, Detroit, MI 48202. Ref #78291. Employer paid ad. An Equal Opportunity Employment-Paid Advertisement.

Product Engineer; 40 hours/week; 8:00am—5:00 pm; $34,000/year. Job requires: Bachelor's degree in Electrical Engineering. Job also requires: 1) 1 college course in technical writing or technical communications; 2) 3 college courses in electrical circuit theory; 3) 3 college courses in electronic circuits; 4) 3 college courses in digital logic design; 5) 2 college courses in systems design which must have emphasized reliability, maintainability, and testability; 6) 2 college courses in electromagnetic theory and applications; 7) 1 college course in Pascal computer language; 8) 1 college course in Fortran computer language; and 9) 1 college course in Assembly computer language. Job duties: Design, develop, and test electronic instruments for use in the evaluation and testing of corporate products. Design and develop high voltage electrical test equipment for vehicle ignition pattern validation. Design and develop electronic hardware to interface with current and future corporate vehicles for accurate ignition system (primary and secondary) testing. Assess competitors' vehicle service products and diagnostic tools/services and compare them to corporate products. Develop

vendor interfaces. Provide gas engine analysis and spark theory expertise as required. Provide overall electronic design expertise as required. Qualified applicants should send resume and verification of requirements to: 7310 Woodward, Room 415, Detroit, MI 48202. Reference #79591. Employer Paid Ad.

Engineer, Senior Design: Resp. for the design & development of high performance CMOS ICs for consumer electronic systems from conception through layout & final test. Also responsible for system analysis, circuit design & computer simulation of mixed analog & digital CMOS ICs, incl. continuous & switched-capacitor filter, video signal gain controlled amplifier & detector, phase locked loop, & other types of logic circuits. Reqs. Ph.D. in Elec. Eng. & 1 yr. of exp. in job offered or in research & development of CMOS analog & digital circuits, implemented on silicon. Also reqs. knowl. of design of high frequency mixed-mode & current-mode analog/digital CMOS ICs; of design of different types of high frequency analog signal processing circuits (video amplifier, filter, modulator, detector, & phase lock loop); of microcomputer architecture, interfacing, & machine language programming; of various CAD tools, Viewlogic, Hspice, Viewsim, SwitchCap, and Dracula (DRC & LVS); of computer systems, Sun/Unix, VAX/VMS, PC/DOS; & of programming in C, Pascal, & Fortran. Salary: $55,000/yr. Job site/intervw site: San Jose, CA. Send ad & resume to Job CP13379, P.O. Box 9560, Sacramento, CA 95823-0560 no later than December 31, 1991. Must have legal right to work. EOE.

Sr. Field Service Engineer. 40 hours/wk., 8:00 am-5:00 pm, Salary: $705/wk. Resp. for on-site electronic hardware maintenance support of GenRad GR16 Very Large Scale Integration (VLSI) test equipment under service contract to customers primarily in the Austin, TX area. These GR16 testers, selling in the 1 & 2 million dollar range, are used to test integrated circuits that comprise many of today's more complex electronic assemblies. Due to the nature of this business, where loss of 1 day of production can amount to tens of thousands of dollars, less than 1 hour response from our Field Service Engineers is required during 24 hour a day, 7 days a week coverage. The Senior Field Service Engineer works independently while reporting to a district office & coordinating with factory personnel. Travel to local customer sites on a daily basis is necessary. Light travel away from home is expected. Also provides a moderate level of software & applications support. Resp. for $175,000.00 worth of inventory located at several facilities. Reqs. Associate's degree in Electronics Technology or equivalent & 3 yrs. exp. in job offered or in electronic maintenance of complex test equipment. Also reqs. min. 3 years esp. with system software, applications, and hardware for semiconductor test systems (this exp. can be gained concurrently with the 3 years esp. listed above; i.e., the position requires a total of 3 years of exp.) Job site/intvw site: Richardson, TX (provides support to customers in the Austin, Texas area). If you are interested in, and qualified for the above position, apply at the Texas Employment Commission, Austin, Texas, or send two (2) resumes to the Texas Employment Commission, TEC Building, Austin, Texas 78778 J.O. #6422202. Ad Paid by an Equal Opportunity Employer.

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Scanning
The Institute

Martha Sloan is 1992 President-Elect

The 1991 general election tally gave the office of President-Elect to Martha Sloan. Runners-up in order of votes received were H. Troy Nagle, Robert T.H. Alden, and Wallace S. Read.

Other elected officers were: Region 1 Director, Joel B. Snyder; Region 3 Director, David A. Conner; Division I Director, Kenneth R. Laker; Division III Director, Frederick T. Andrews; Division V Director, Bill D. Carroll; Division VII Director, Robert A. Dent; Division IX Director, Jan Brown; Region 2 Director-Elect, Arthur Van Gelder; Region 4 Director-Elect, Vernon D. Albertson; Region 8 Director-Elect, Charles W. Turner; Region 9 Director-Elect, Hugo M. Fernandez Verstegen; Region 10 Director-Elect, Tsuneo Nakahara; and Region 3 Vice Chairman, Deborah M. Powers.

A proposed amendment to the IEEE consitution to change the office of Vice President-Professional Activities to Vice President-United States Professional Activities was defeated. The amendment also would have had the Vice President-United States Professional Activities elected by the United States membership rather than by the IEEE Assembly [THE INSTITUTE, Nov./Dec., p. 1].

AT&T outage causes havoc

On Sept. 17 the air traffic control system in much of the northeastern United States was knocked out as were many of New York City's telephone links. The havoc was traced to a series of events and nonevents that caused key transmission equipment to run out of electric power. When a wrongly set safety device switched equipment from diesel generators to standby batteries at an AT&T Co. office in lower Manhattan, no one noticed the changeover despite audible and visual alarms. By the time the changeover was finally recognized hours later, the batteries were so drained that they could only be recharged by disconnecting them from the load. By then, transmission facilities had begun to shut down [THE INSTITUTE, Nov./Dec., p. 1].

IEEE media briefing held

Fuzzy logic, virtual reality, and multimedia personal communications were key topics at the annual media briefing held in New York City in October.

Jim Bezdek of the University of West Florida, Pensacola, noted that the Japanese were running away with commercial applications of fuzzy logic. Thomas P. Caudell of Boeing Computer Services, Seattle, Wash., discussed bringing information to the manufacturing floor without paperwork. This could be done, he said, by using a computer-aided design system that would provide a three-dimensional assembly image —virtual reality—to workers on the factory floor.

Hugh Chang, Microsoft Corp., Redmond, Wash., talked of such multimedia applications as a dictionary of quotations, where a quote is spoken while displayed on a screen, and a music course on Beethoven's Ninth Symphony that enables a listener-viewer to read about the historical background of the piece, examine its musical architecture, review a measure-by-measure audio commentary, or hear the piece in its entirety [THE INSTITUTE, Nov./Dec., p. 1].

Coming
in Spectrum

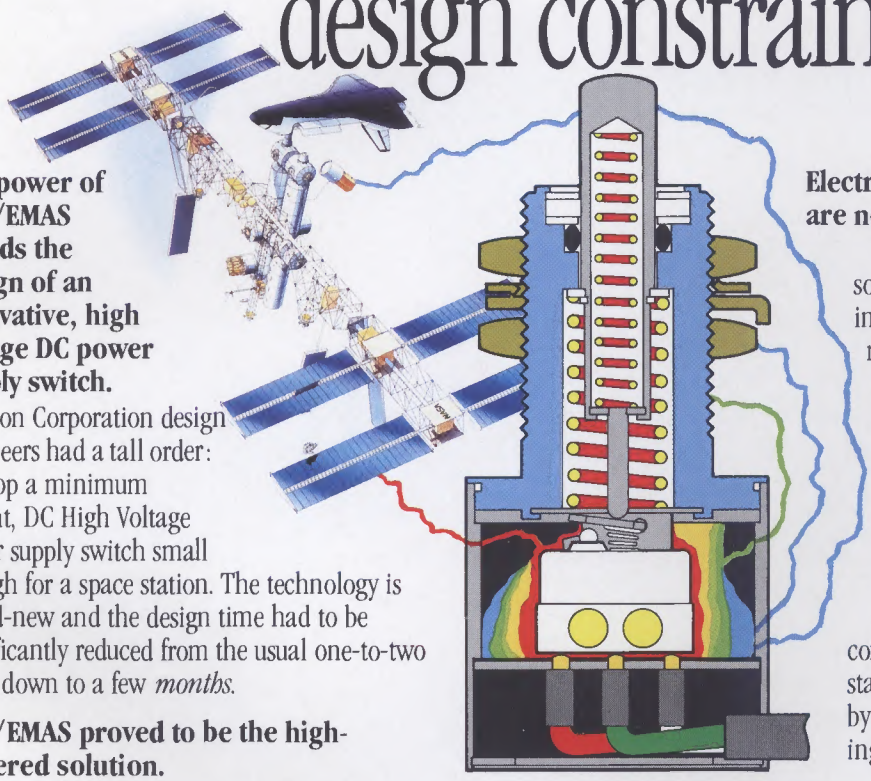
"TECHNOLOGY '92," *IEEE Spectrum*'s annual overview of existing hardware and software, will be published in January. It will spotlight the major trends and advances in the fields covered by the magazine throughout the year.

Technical areas to be reviewed are personal computers, workstations, software, minis, mainframes, supercomputers, telecommunications, data communications, solid state, test and measurement, industrial electronics, power and energy, consumer electronics, transportation, aerospace and military, and medical electronics.

Each article will open with a brief discussion by a recognized expert of the burning issue or issues and the most significant developments in that field. The body of each article, written by a *Spectrum* editor, will detail the major developments in the field during the previous year in terms of both the hardware and the software available.

Experts for the issue and their areas are: Forest Baskett, Silicon Graphics Inc., PCs and workstations; Wayne H. Wolf, Princeton University, software; David Patterson, University of California at Berkeley, minicomputers and mainframes; Israel Zibman, GTE Laboratories, telecommunications; Victor B. Lawrence, AT&T Bell Laboratories, data communications; Frederick R. Hume, Keithley Instruments Inc., test and measurement; Javier Uceda, Universidad Politécnica de Madrid, industrial electronics;Carl Weinberg, Pacific Gas & Electric Co., power and energy; Leander H. Hoke Jr., Philips Consumer Electronics Co., consumer electronics; Tristan A. Kneschke, LTK Engineering Services, transportation; Thomas Fagan Jr., ITT Defense, aerospace and military; and Dov Jaron, National Science Foundation, medical electronics.

How EATON turned the power on when faced with severe design constraints.

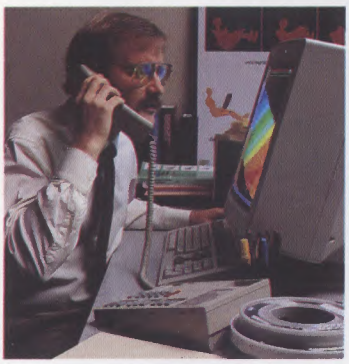


The power of MSC/EMAS speeds the design of an innovative, high voltage DC power supply switch.

Eaton Corporation design engineers had a tall order: develop a minimum weight, DC High Voltage power supply switch small enough for a space station. The technology is brand-new and the design time had to be significantly reduced from the usual one-to-two years down to a few *months*.

MSC/EMAS proved to be the high-powered solution.

Eaton built finite element models of electromagnetic power switches. MSC/EMAS then calculated the magnetic flux distribution of each model under varying conditions. By altering the material characteristics, excitations and sizes, Eaton was able to "design" the model that met its parameters. When building and testing the actual switch, Eaton found the results matched MSC/EMAS model results to within 5%. Using MSC/EMAS eliminated the need for repetitive prototyping and testing. As a result, Eaton engineers cut normal design time by over 75%.



Electric and magnetic field problems are no problem for MSC/EMAS.

Electrical engineers use MSC/EMAS to solve electric and magnetic field problems involving linear, nonlinear and anisotropic materials. The program lets users analyze the entire range of electromagnetic behavior... from electrostatics and nonlinear magnetostatics to eddy currents and wave propagation. What's more, these varied applications can be accurately simulated under one powerful, easy-to-use program.

MSC/EMAS is available on a variety of computer platforms, from engineering workstations to supercomputers, and is backed by the most comprehensive support, training and documentation in the industry.

No wonder MSC/EMAS is the world's premier software package for electromagnetic analysis.

Current information on our concurrent family of products.

Apply MSC/EMAS to your company's toughest electromagnetic field problems. For videos or brochures on MSC/EMAS or any member of MSC's complete family of computer-aided engineering software, call us at (800) 336-4858 or (213) 258-9111. We'll help you turn the power on.

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